# FAME PDR
# Mechanical Design Subsystem

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# Subsystem Requirements (1 of 4)

- Design for 3712A PAF Marmon Clamp FV to LV Interface
  - Comply
- Design for Instrument Interface as Defined by the Observatory to Instrument Interface Control Document (ICD)
  - Comply.  However, Select Star Tracker to Finalize Mechanical Interface
- Provide Shade for the Instrument From the Sun's Rays at an Orientation of 35 +/- 5 Degree During Data Collection Phase
  - Comply
- Design for Payload Static Envelope of the Delta II 7425-10 Fairing As Defined by the Delta II Payload Planners Guide, October 2000
  - Comply

# Subsystem Requirements (2 of 4)

- Provide 4,750.0 in^2 of Solar Cells Area
  - Comply
- Provide 1,550.0 in^2 of Radiating Surface on the Electronics Deck
  - Comply if an Additional 500.0 in^2 of Area Is Utilized Under the Trim Tabs or Trim Areas
- The FV CG Lateral Offset Shall Not Exceed 0.5 Inch From the FV Geometric Centerline Prior to Star 30BP Ignition
  - Comply
- FV Spin Axis Alignment Shall Not Exceed 1.5 Degrees From the FV Geometric Centerline Prior to Star 30BP Ignition
  - Comply

# Subsystem Requirements (3 of 4)

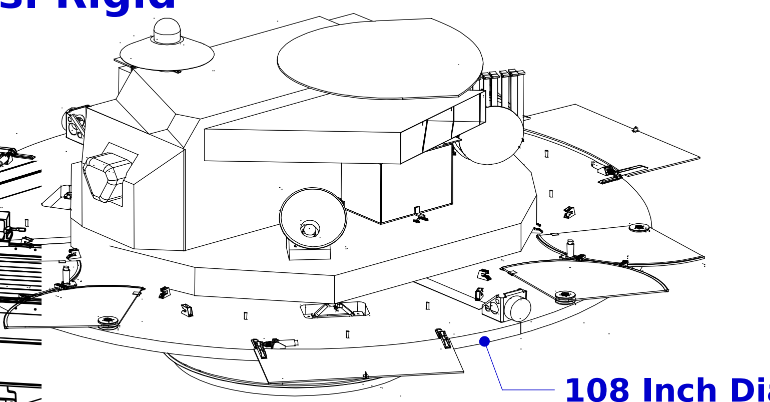
- **Observatory Lateral CG Offset Shall Not Exceed 0.39 Inch (10 mm) From the Observatory Geometric Centerline During Data Collection Phase**
  - **Comply**
- **Observatory Axial CG Location Shall Be 6.69 Inches (0.17 m) to 8.27 Inches (0.21 m) From the Solar Array Optical Surface During Data Collection Phase**
  - **Comply**
- **Observatory Spin Axis Alignment Shall Not Exceed 0.5 Degree From the Observatory Geometric Centerline Prior to Launch**
  - **Comply**
- **Observatory Izz Spin Inertia Shall Be 738,100.0 (216.0 kg*m^2) to 902,100.0 lbm*in^2 (264.0 kg*m^2) During Data Collection Phase**
  - **Comply**

# Subsystem Requirements (4 of 4)

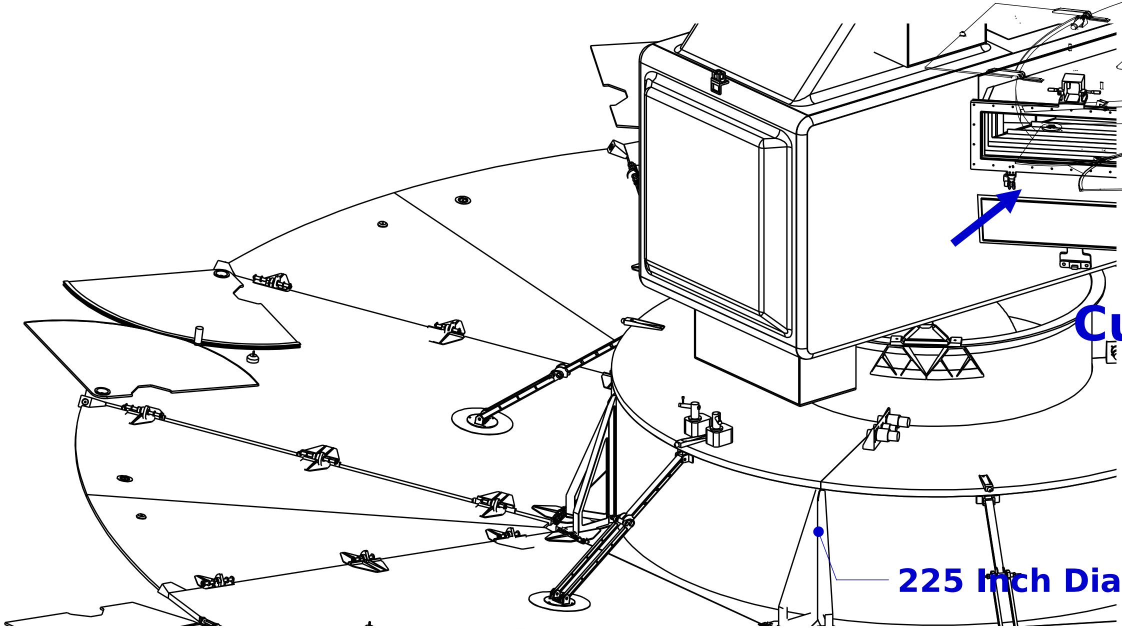
- Provide Maximum Control Authority With an Unobstructed Field of View for the RCS Thrusters During All Phases of the Mission
  - Comply
- Observatory Ixx and Iyy Transverse Inertias Shall Be 75 to 94% of Izz With No More Than 4% Variation Between the Two During Data Collection Phase
  - Current Mass Properties Exceeds the 4% Variation. Optimize Component Layout and/or Add Ballast Mass
- The Total FV Mass Shall Not Exceed the Delta II 7425-10 Capability
  - Current Design Shows Inadequate Program Mass Margin. Reduce Mass or Baseline Larger Launch Vehicle, 7925-10
- Observatory Ixy Transverse Inertia Shall Be No More Than 2% of the Izz Spin Inertia During Data Collection Phase
  - Current Mass Properties Exceeds the Requirement. Optimize Component Layout and/or Add Ballast Mass

# Mechanical Design Trades

- Solar Array Layout Trades
  - Multiple vs. Single Hinge and Deployable vs. Rigid
- Primary Structure Mass Reduction Trades
  - Composite vs. Aluminum and Load Path Optimization
- Antenna Location Trades
  - SC Bus vs. Instrument and Deployable vs. Rigid
- Star Tracker Location Trade
  - SC Bus vs. Instrument



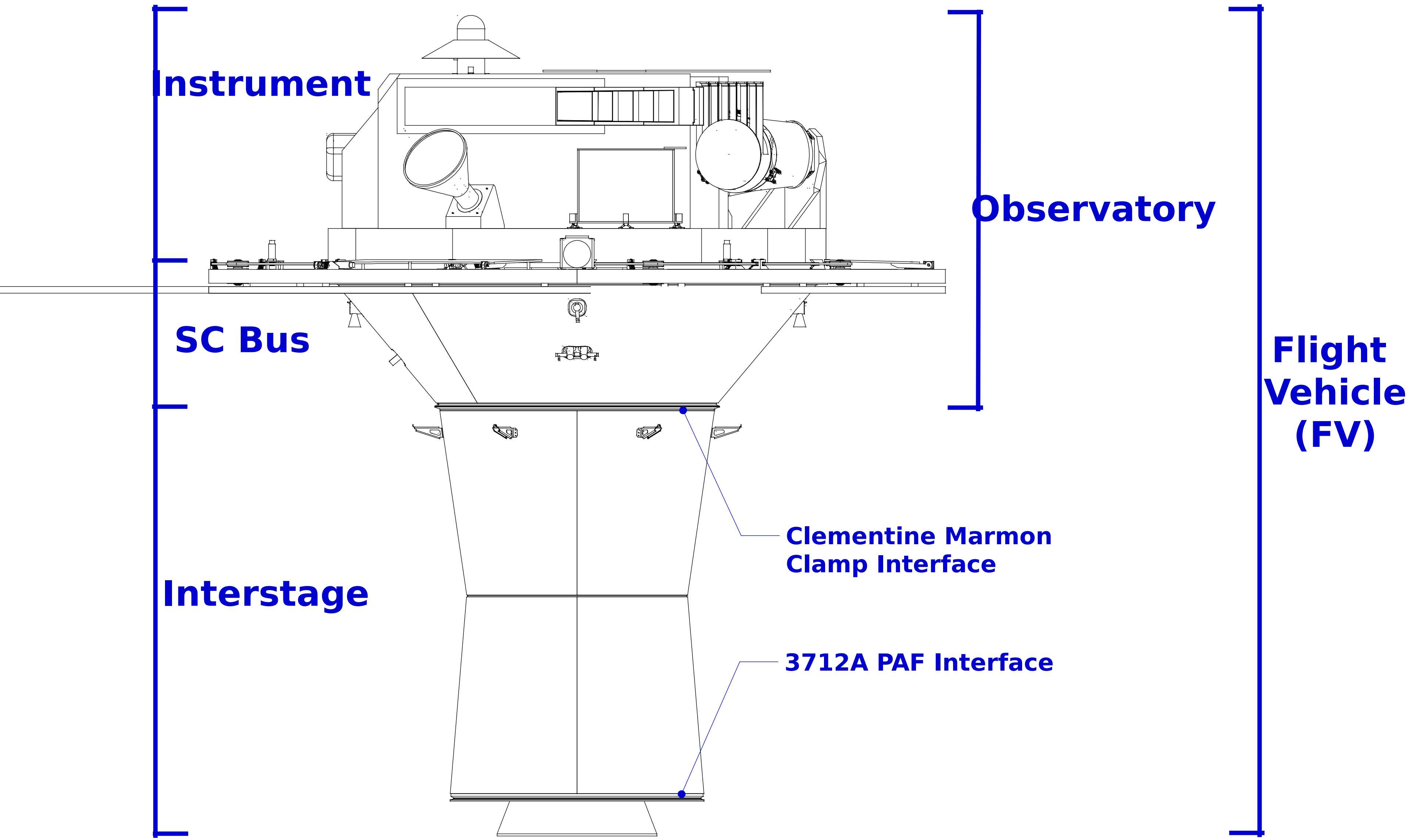

Current Design Layout



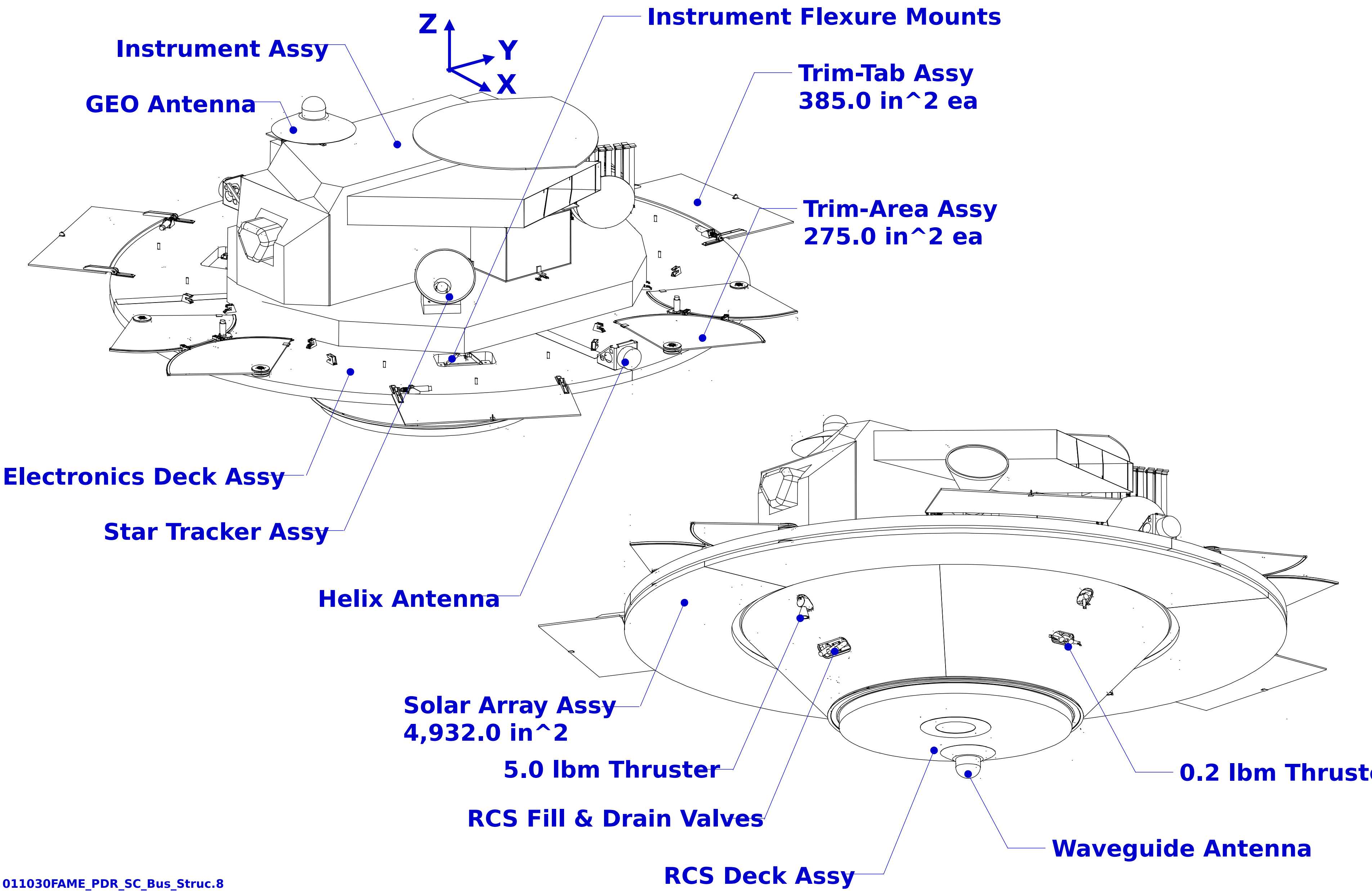

Not to Scale

6/20/01 Design Layout

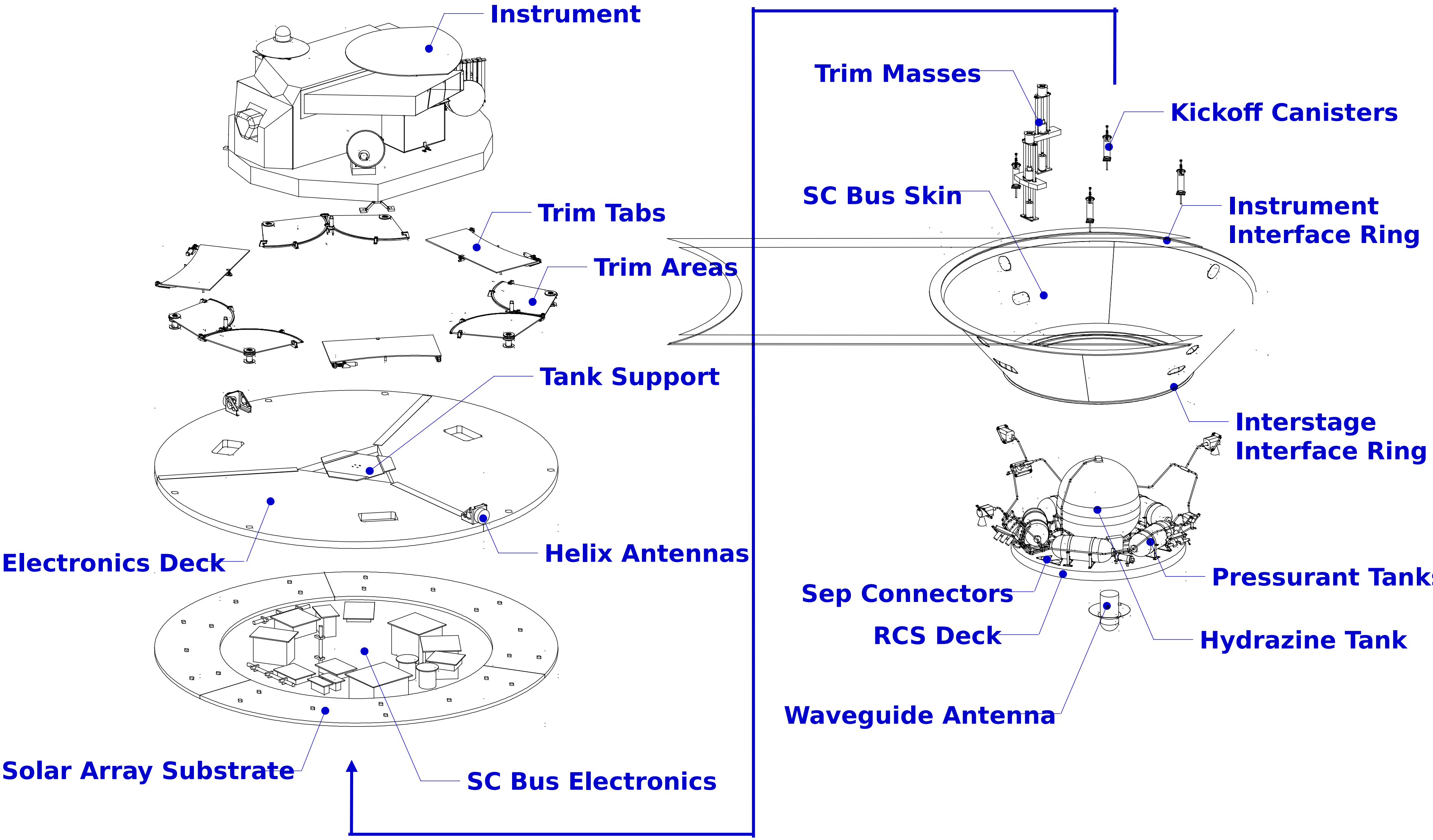
# Mechanical Design (1 of 5)



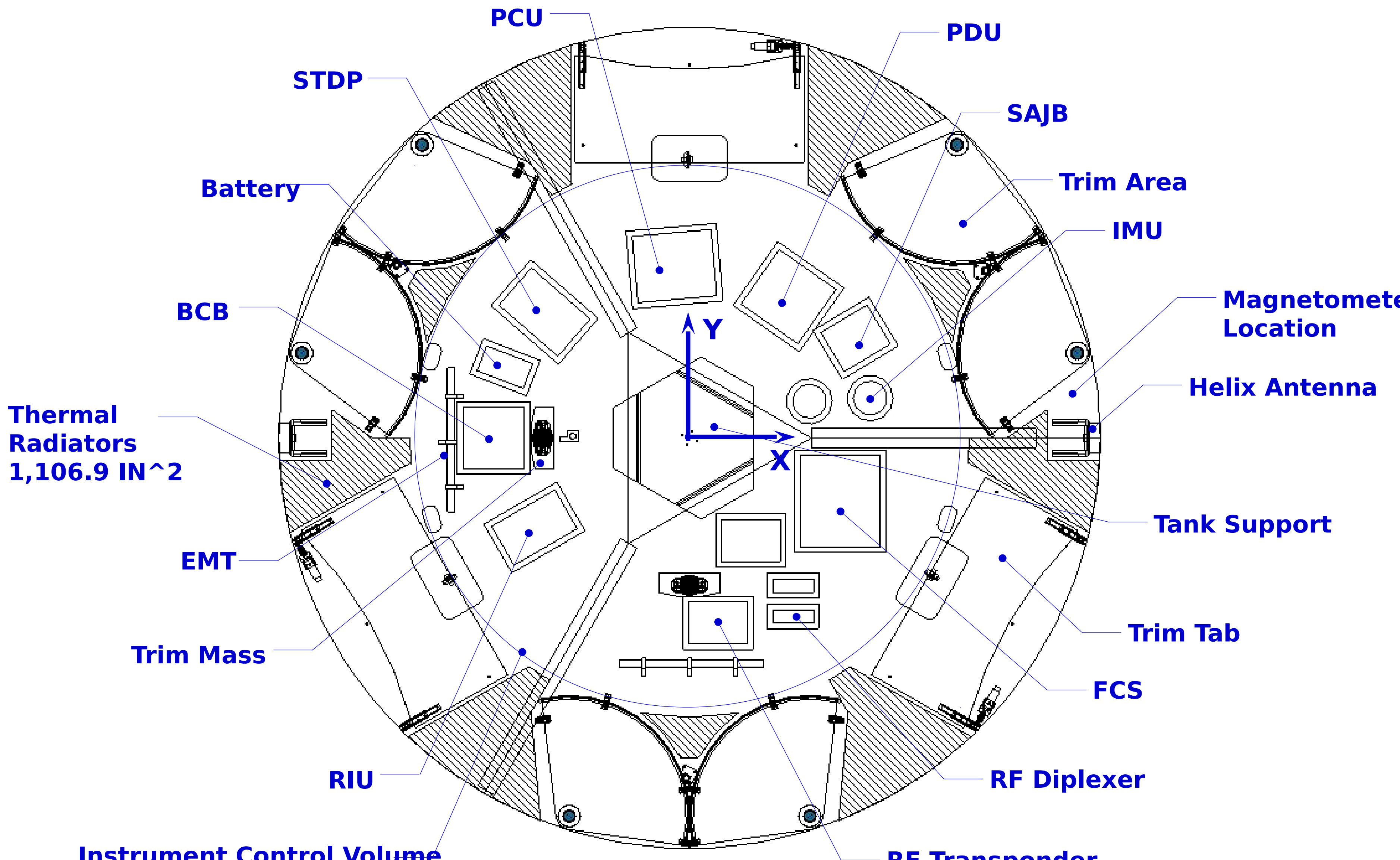
# Mechanical Design (2 of 5)



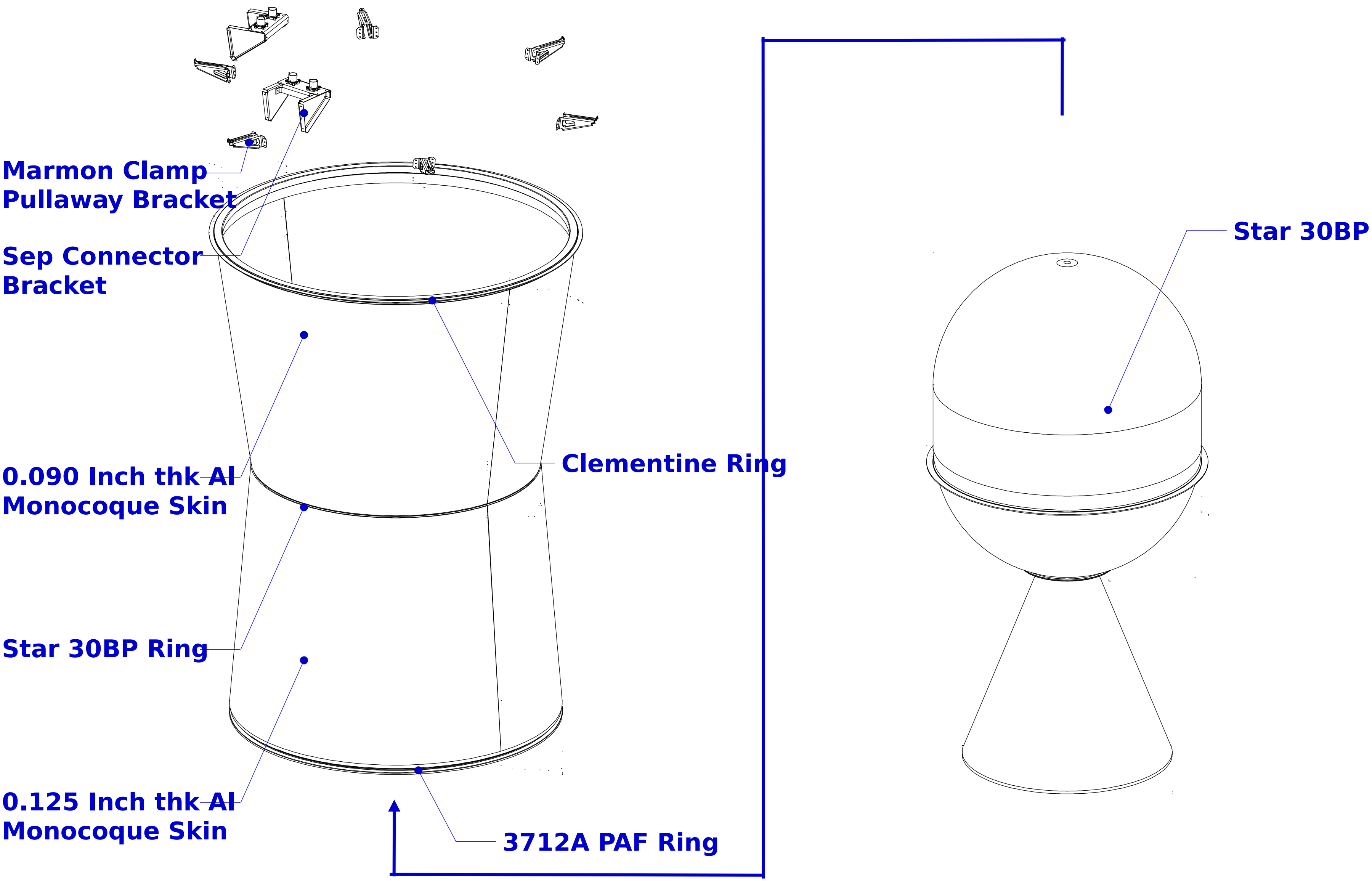
# Mechanical Design (3 of 5)



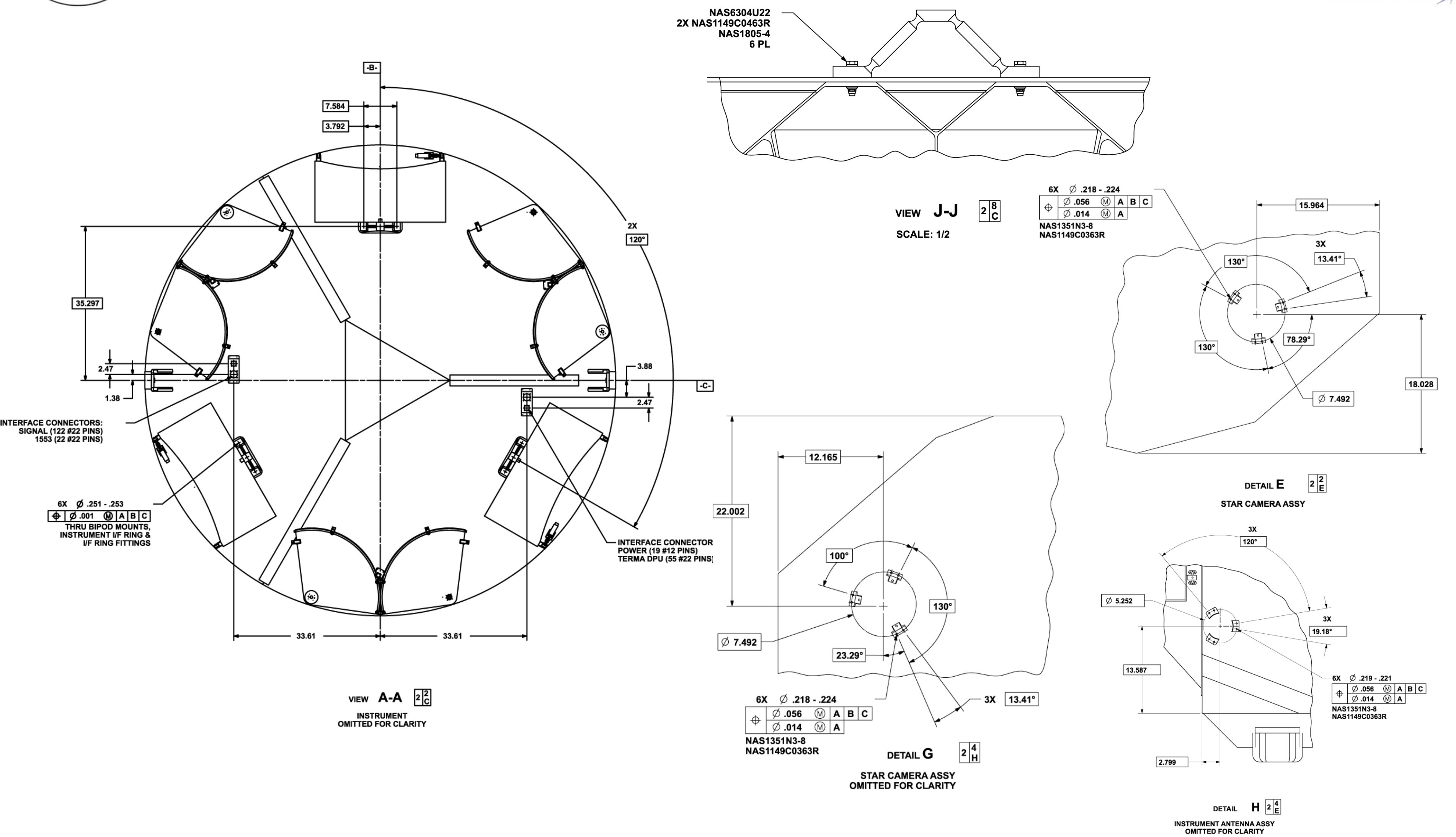
# Mechanical Design (4 of 5)



# Mechanical Design (5 of 5)

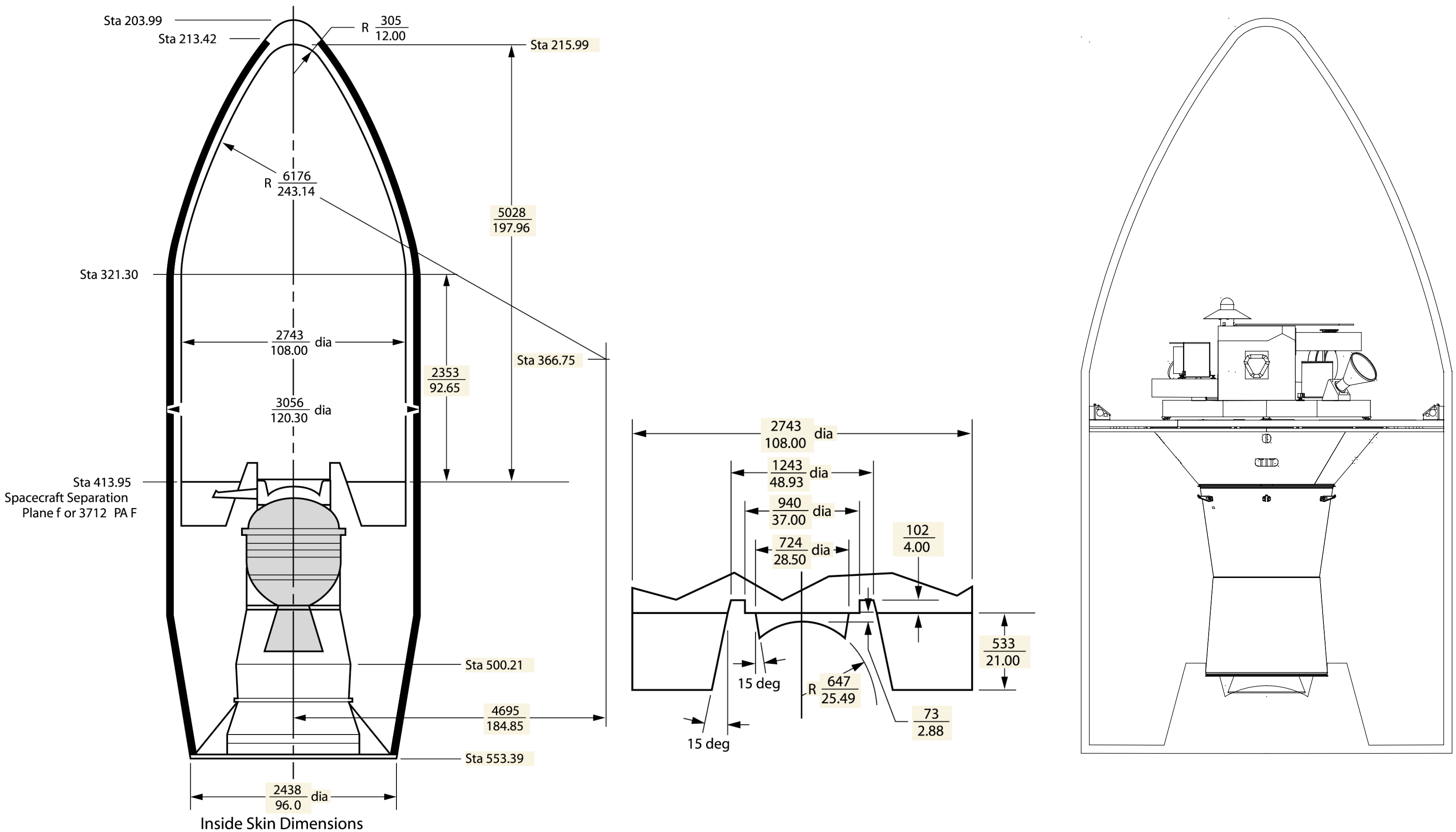


# Mechanical Interfaces (1 of 2)



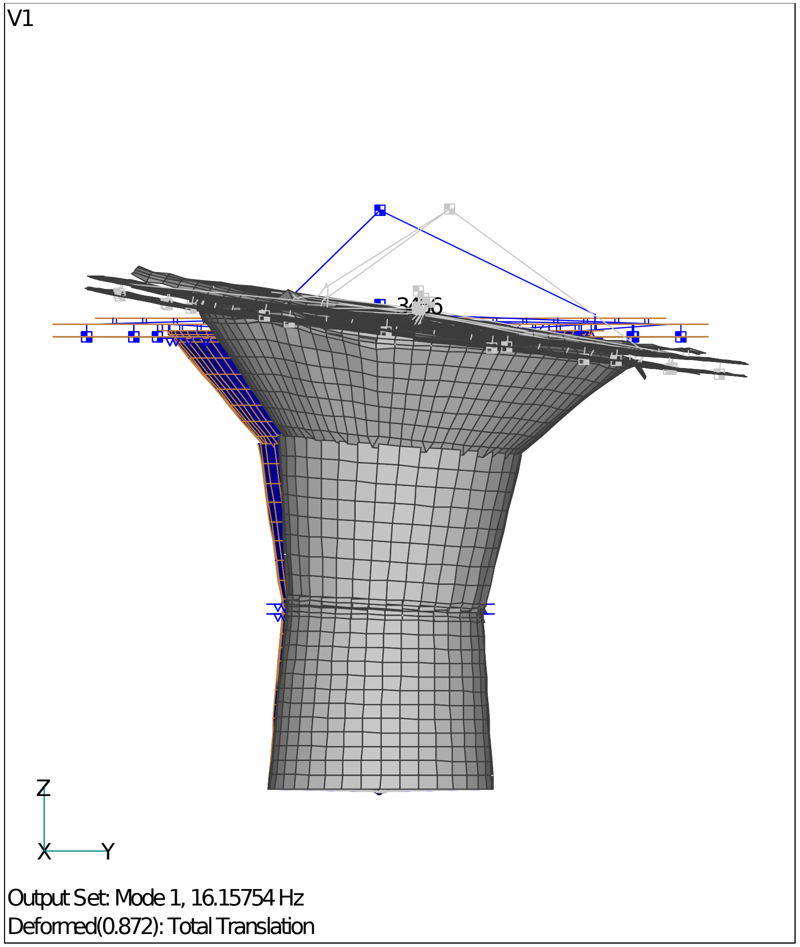

## SC Bus / Instrument Mechanical Interface (FM-IC-0005)

# Mechanical Interfaces (2 of 2)




## 7425-10 LV Static Fairing Envelope

# Mechanical Analysis (1 of 3)




**M O D E L   S U M M A R Y**

```
NUMBER OF GRID      POINTS   =     6086
NUMBER OF CBAR      ELEMENTS =       64
NUMBER OF CBUSH     ELEMENTS =       95
NUMBER OF CELAS2    ELEMENTS =      223
NUMBER OF CONM2     ELEMENTS =       68
NUMBER OF CQUAD4    ELEMENTS =     5372
NUMBER OF CTRIA3    ELEMENTS =      138
NUMBER OF PLOTEL    ELEMENTS =       95
NUMBER OF RBE2      ELEMENTS =       12
NUMBER OF RBE3      ELEMENTS =       30
```

| | | | |
|---|---|---|---|
| **MASS (lbs.)** | 2456.64 | | |
| **CG (in.)** | **X** | **Y** | **Z** |
| | -0.08 | 0.21 | 57.79 |
| **MASS MOMENT OF INERTIA** | **Ixx** | **Iyy** | **Izz** |
| | 2483441 | 2394965 | 1241586 |
| | **Pxz** | **Pyz** | **Pxy** |
| | 4304 | 9072 | 43900 |

**Flight Vehicle First Bending Mode (16.2 Hz)**

# Mechanical Analysis (2 of 3)

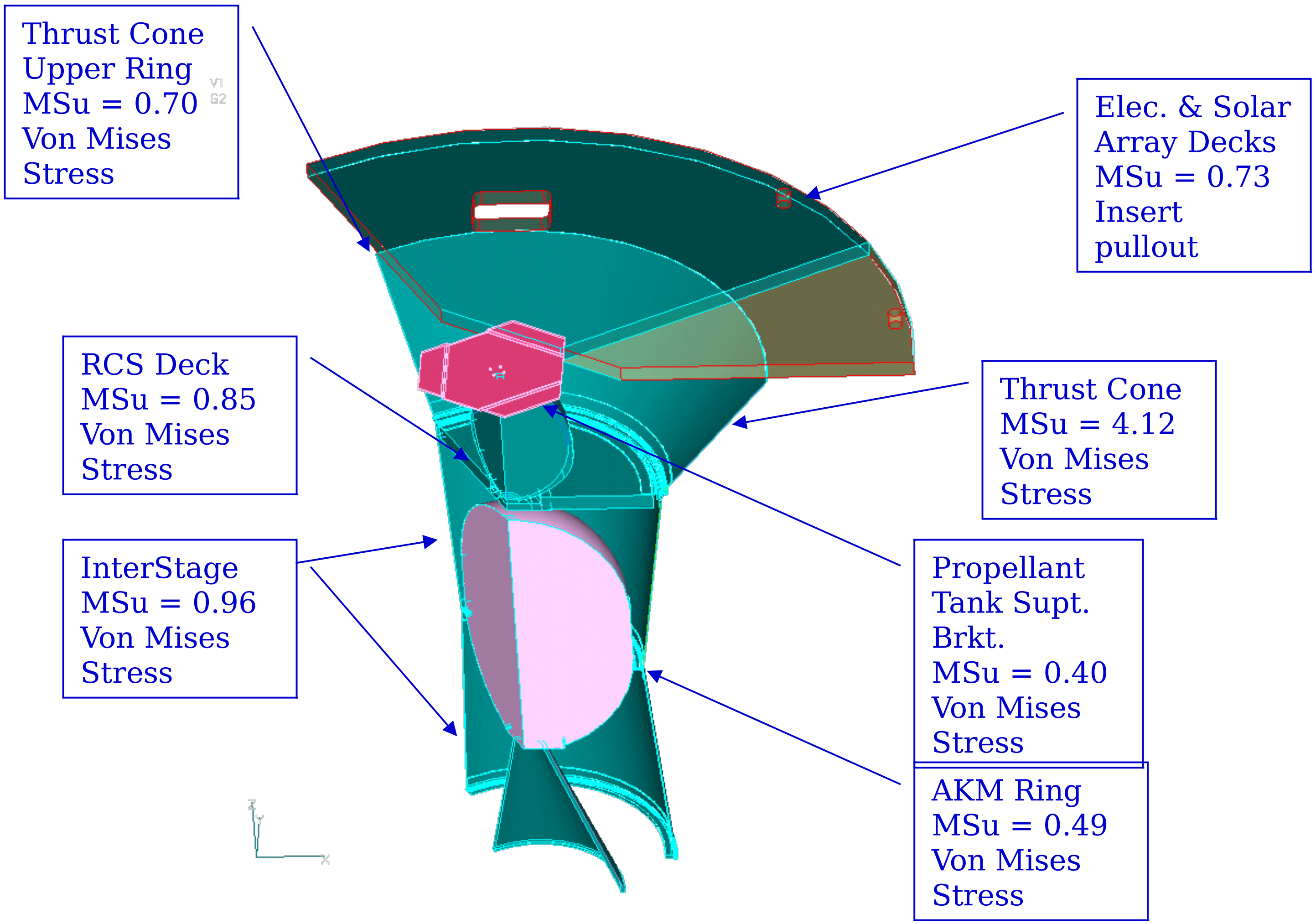
| MODE | FREQ. (Hz) | ABS(X) | ABS(Y) | ABS(Z) | ABS(RX) | ABS(RY) | ABS(RZ) | MODE DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| 1 | 16.2 | 1.0% | **41.1%** | 0.0% | **9.9%** | 1.4% | 0.0% | 1st bending mode; Min. requirement: 15 Hz |
| 2 | 16.2 | 1.0% | 0.0% | 0.0% | 0.0% | 1.0% | 0.0% | NSM |
| 3 | 17.0 | **43.0%** | 1.0% | 0.0% | 0.0% | **44.9%** | 0.0% | 2nd bending mode; Min. requirement: 15 Hz |
| 4 | 18.8 | 0.2% | 2.4% | 0.0% | 2.8% | 0.1% | 0.0% | NSM |
| 5 | 19.8 | 0.1% | 0.1% | 1.0% | 0.0% | 0.2% | 0.0% | NSM |
| 6 | 21.3 | 0.0% | 0.1% | 0.2% | 0.1% | 0.1% | 0.0% | NSM |
| 7 | 23.9 | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | NSM |
| 8 | 25.6 | 0.2% | 0.0% | 0.3% | 0.1% | 0.0% | 0.0% | NSM |
| 9 | 32.4 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | NSM |
| 10 | 32.4 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | NSM |
| 11 | 37.4 | 0.1% | 0.0% | 1.2% | 0.0% | 0.0% | **83.1%** | Torsional mode |
| 12 | 38.6 | 0.0% | 0.0% | 0.7% | 0.0% | 0.0% | 0.2% | NSM |
| 13 | 38.7 | 0.2% | 0.8% | **26.5%** | 0.1% | 0.1% | 2.7% | Axial Mode; Min. requirement: 35 Hz |
| 14 | 40.7 | 3.3% | **8.8%** | 1.6% | 3.8% | 0.4% | 0.0% | Elec. Deck Bending |
| 15 | 44.0 | **13.5%** | 3.3% | 0.2% | 0.5% | 0.8% | 0.0% | Lateral Mode |
| 16 | 45.6 | 0.9% | **6.3%** | 0.3% | **30.0%** | 0.1% | 0.0% | Lateral Mode & Bending |
| 17 | 47.6 | 1.4% | 0.2% | 0.5% | 4.1% | 2.0% | 0.2% | NSM |
| 18 | 48.9 | 0.1% | 0.0% | 2.9% | 1.7% | 0.1% | 0.1% | NSM |
| 19 | 49.9 | 0.1% | 0.5% | 0.2% | 0.8% | 0.2% | 0.1% | NSM |
| 20 | 52.0 | 0.5% | 0.8% | 4.4% | **9.2%** | 0.7% | 0.0% | Elec. Deck |

| | | | | | | |
|---|---|---|---|---|---|---|
| PERCENT TOTAL | 65.7% | 65.5% | 40.0% | 63.2% | 52.1% | 86.4% |

NSM: Non-structural mode defined as the participation factor is less than 5%.

## Flight Vehicle Modal Mass Participation Summary

# Mechanical Analysis (3 of 3)




**Flight Vehicle Margin of Safety Summary**

# Mass Summary

| | Mass (lbm) | Uncert (lbm) | Total Mass (lbm) |
|---|---|---|---|
| INSTRUMENT ASSY | 426.86 | 85.54 | 512.40 |
| SC BUS ASSY | 633.03 | 82.04 | 715.07 |
| - GFE on Instrument | 20.00 | 5.00 | 25.00 |
| - Mechanical Subsystem | 206.45 | 24.31 | 230.76 |
| - RCS Dry Subsystem | 49.25 | 3.55 | 52.80 |
| - RCS Propellant | 88.00 | 22.00 | 110.00 |
| - ADCS Subsystem | 20.24 | 1.01 | 21.25 |
| - Mechanism Subsystem | 46.76 | 4.32 | 51.08 |
| - EPS Subsystem | 103.40 | 12.74 | 116.14 |
| - RF Subsystem | 25.59 | 2.40 | 27.99 |
| - CT&DH Subsystem | 40.30 | 3.48 | 43.78 |
| - TCS Subsystem | 33.04 | 3.23 | 36.27 |
| INTERSTAGE ASSY | 1228.25 | 21.17 | 1249.42 |
| - Mechanical Subsystem | 118.15 | 14.09 | 132.24 |
| - TCS Subsystem | 15.55 | 0.76 | 16.31 |
| - STAR 30 BP Case Assy | 72.00 | 3.60 | 75.60 |
| - STAR 30 BP Propellant | 998.90 | 0.00 | 998.90 |
| - Miscellaneous | 23.65 | 2.72 | 26.37 |
| FLIGHT VEHICLE ASSY | 2288.14 | 188.75 | 2476.89 |

# Mass Mitigation

- **Reduce Solar Array Substrate Mass**
  - **Change Baseline Design From .005 in Thick 4 Ply Face Sheet to .002 in Thick 3 Ply.  Perform Analysis (~ 5 to 7 lbm Savings)**
- **Reduce Interstage Structural Assembly Mass**
  - **Investigate Changing Design to One Single Machined Piece. Allows for a More Efficient Structural Design. Perform Analysis (~ 5 to 10 lbm Savings)**
- **Reduce FAME Instrument Assembly Mass**
  - **Mass Mitigation as Stated in Instrument Presentation**
- **Reduce GFE Mass on FAME Instrument**
  - **More Refine GFE Component Masses (~ 5 to 7 lbm Savings)**
- **Composite SC Bus and Interstage Primary Structure**
  - **Composite Primary Structure Could Increase Mechanical Budget by 1.0 Million   (~ 25 to 35 lbm Savings)**

# Open Issues

- Current Design Shows Inadequate Mass Margin on Flight Vehicle
  - Investigate Mass Mitigation Approach
  - Investigate 7925-10 Delta II LV Baseline
- Observatory Ixx and Iyy Transverse Inertias
  - May Need to Add Ballast Mass
- Observatory Ixy Transverse Inertia
  - May Need to Add Ballast Mass
  - Difficult to Verify by Test
- Star Tracker
  - Select Baseline
- Magnetometer and EMT Locations
  - Will Current Locations Effect Components Performance
- Electronics Deck Splices
  - Redesign to Better Transfer Shear
- Solar Cell Area
  - Very Little Room for Growth

# Mechanical Schedule

| TASK | START DATE | FINISH DATE |
|---|---|---|
| PDR | 10/30/01 | 10/31/01 |
| Finalize Flight Vehicle Design | 11/15/01 | 3/20/02 |
| Analysis Flight Vehicle Design | 12/21/01 | 6/12/02 |
| Detailed Part Drawings | 4/16/02 | 8/9/02 |
| CDR | 8/13/02 | 8/14/02 |
| Fabricate EM SC Parts | 8/17/02 | 12/16/02 |
| Fabricate EM Interstage Parts | 8/17/02 | 12/16/02 |
| Assemble EM SC | 1/30/03 | 2/14/03 |
| Assemble EM Interstage | 1/10/03 | 2/14/03 |
| Assemble EM Flight Vehicle | 2/17/03 | 2/21/03 |
| EM Flight Vehicle System Testing | 2/21/03 | 7/7/03 |
| Flight FEM Model Correlation | 3/20/03 | 5/20/03 |
| Test Verified Coupled Loads Analysis | 5/21/03 | 10/21/03 |
| Assemble Flight SC Bus | 420/2003 | 12/19/03 |
| Assemble Flight Interstage | 4/210/2003 | 7/18/03 |

# Mechanical Conclusion

- **Insufficient Mass Margin Using the 7425-10 Launch Vehicle**
- **Refine Existing 31 Inch Propellant Tank / Star 37 XFP Flight Vehicle Design for the 7925-10 Launch Vehicle Configuration**
  - **Preliminary Layout of This Design Looks Promising**
  - **Continue Layout to Insure All Components Fit Within This Design**
  - **Perform New Mass Properties Report**
  - **New Design Will Have Little Effect on FAME Instrument**

# Backup – Requirements (1 of 6)

- Outgassing
  - Materials Exhibiting Total Mass Loss (TML) of 1.0% or Less and Collected Volatile Condensable Material (CVCM) Values of 0.1% or Less Shall Be Used
- Structural and Metallic Materials
  - Shall Be Corrosion Resistant by Nature or Shall Be Corrosion Inhibited by Means of Protective Coatings. Base Metals That Form Galvanic Couple Shall Be Plated With Materials That Reduce Galvanic Potential
- Magnetic Materials
  - Use of Magnetic Materials Should Be Avoided Whenever Possible
- Finishes
  - Cadmium, Tin, and Zinc Coatings Shall Not Be Used
- Stress Corrosion
  - Materials Shall Be Selected to Control Stress Corrosion Cracking in Accordance With “Design Criteria for Controlling Stress Corrosion Cracking”, MSFC-SPEC-522A

# Backup – Requirements (2 of 6)

- Corona Suppression
  - Observatory Shall Be Designed to Minimize Corona Discharge in all Normal Operating Environments
- Nameplating and Product Marking
  - Components Shall Be Identified by Part Number and Serial Number or Lot Number
- Safety
  - Design, Operation, and Testing of the Observatory Space Segement and Its GSE Shall Satisfy the Requirements of EWRR 127-1, Chapters 3 and 5
- Positive Locking Devices
  - Screw-Type Hardware Shall Employ Positive Locking. If Used, Safety Wiring Shall Be According to MS33540
- Drawings
  - Specifications and Hardware Shall Be Supported by Drawings According to the Guidelines Set Forth in MIL-DTL-31000 and DOD-D-1000, or Their Supplier Equivalents

# Backup – Requirements (3 of 6)

- **Grounding**
  - **The Spacecraft Bus Shall Have a Metal to Metal Impedance of 2.5 mohms or Less for the Electronics Box to Mounting Deck Interface in Addition to the a Metal to Composite Impedance of 10 ohms or Less**
- **Maintainability**
  - **Flight Hardware Shall Be Designed for Service and Access, Where Practical. Positive Positioning and Alignment Features Shall Be Provided**
- **System Effectiveness Model**
  - **Shall Be Developed That Correlates the Structural Modes to Within 5 Percent of Experimental Results. The Analytical Model Should Be Written in NASTRAN or Equivalent**
- **Sun Sensor Locations**
  - **to Provide an Unobstructed Field of View During all Phases of the Mission**
- **Trim Tab Location**
  - **to Provide the Maximum Control Authority During the Operational Phase of the Mission**

# Backup – Requirements (4 of 6)

- Trim Area Locations
  - to Provide the Maximum Control Authority During the Operational Phase of the Mission
- Trim Mass Locations
  - to Provide the Maximum Control Authority During the Operational Phase of the Mission
- IMU Locations
  - to Provide the Maximum Shielding from Radiation. In Addition, Provide an Optical View of the Reference Retro-Reflector for System Integration
- Propellant Fill and Drain Valve Locations
  - Shall Be Easily Accessible During Integration, Test, and Field Operation Phases of the Mission
- Star 30BP Location
  - To Provide an Unobstructed Path for the Plume During its Operation
- Ordnance Arming Plug Location
  - Shall Be Easily Accessible During Integration, Test, and Field Operation Phases of the Mission

# Backup – Requirements (5 of 6)

- RF Antenna Locations
  - to Provide an Unobstructed Field of View During all Phases of the Mission
- Instrument Orientation
  - Such That the Entrance Apertures Have an Unobstructed Field of View During All Phases of the Mission
- Lifting Attach Points
  - Shall Be Provided On the Flight Vehicle During Launch Vehicle Integration
- Non-Flight Protective Covers
  - Shall Be Provided for Major Components During Ground Handling and System Integration
- Design Limit Loads
  - All Structural Systems and Components Shall Be Capable of Surviving All Loads for All Environments as Defined by the "Design, Loads, and Analysis Plan", NCST-D-FM017
- FV to LV Ground
  - The FV Shall Be Equipped With an Accessible Ground Attachment Point to Which a Conventional Alligator-Clip Ground Can Be Attached

# Backup – Requirements (6 of 6)

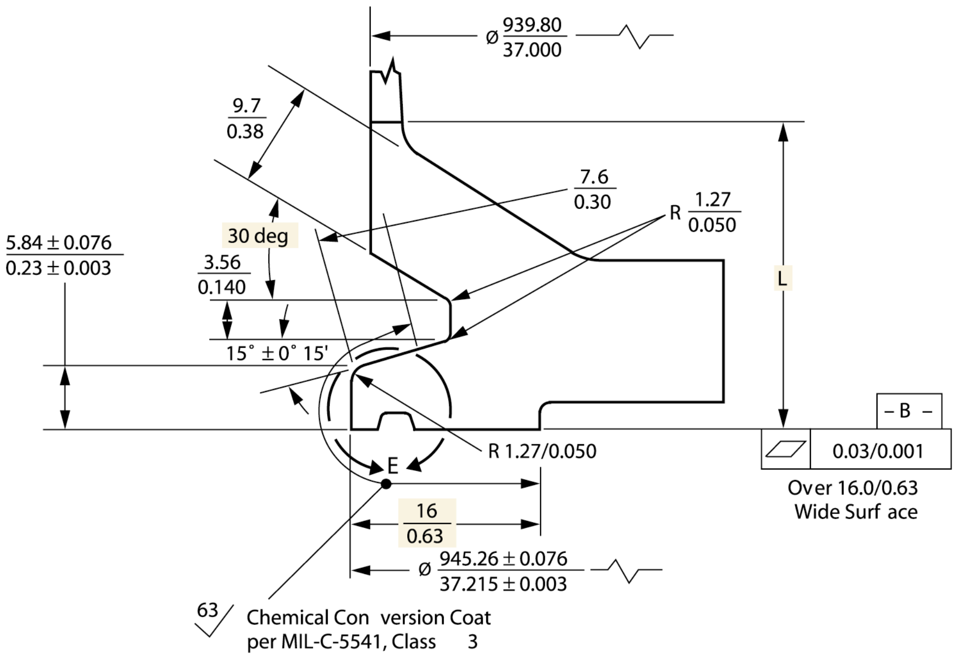
- Factors of Safety (FOS)
  - The Flight Vehicle Shall Be Analyzed Using the FOS as Defined in the "Design, Loads, and Analysis Plan", NCST-D-FM017

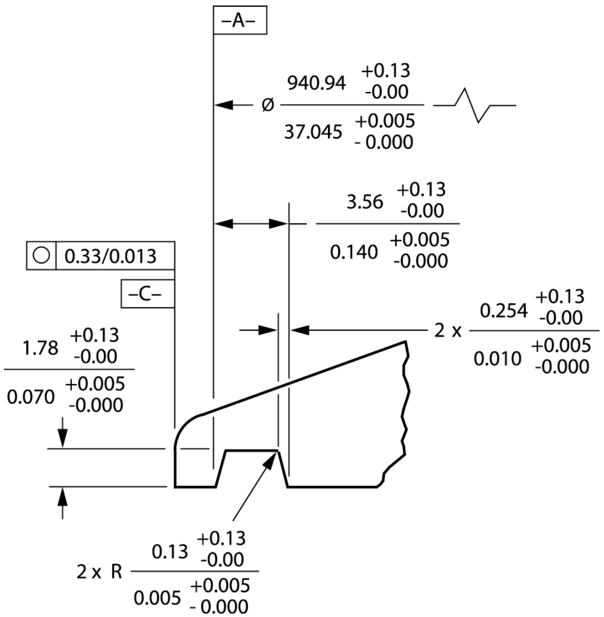
| | Test | No Test |
|---|---|---|
| Yield | 1.10 | 1.60 |
| Ultimate | 1.40 | 2.00 |
| Composite Ultimate | 1.50 | NA |
| Local Buckling | 1.25 | 1.60 |
| Overall Stability | 1.40 | 2.00 |
| Bonded Joint, Yield | 1.15 | NA |
| Bonded Joint, Ultimate | 1.50 | NA |
| Mechanical Test Level | 1.05 | NA |

- Natural Frequency
  - The Flight Vehicle Shall Have a First Natural Frequency No Less Than That Defined in the "Design, Loads, and Analysis Plan", NCST-D-FM017

| | |
|---|---|
| Subsystems | >= 50 Hz |
| System, Axial | >= 35 Hz |
| System, Lateral | >= 15 Hz |

# Backup – Mech Interfaces (1 of 2)

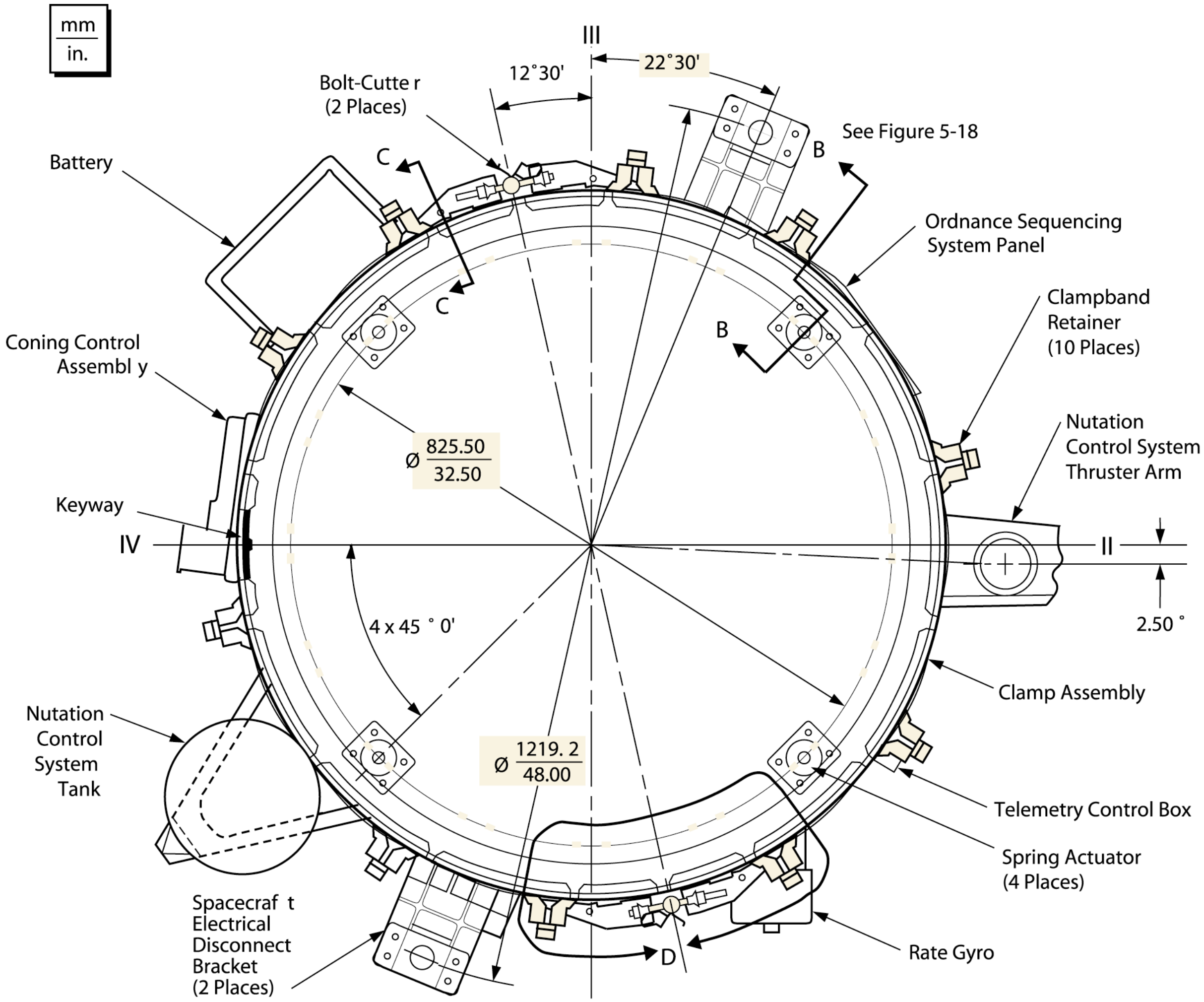



**Cross-Section Area = 0.763 in^2 +- 15%**
**Area Inertia = 0.110 in^4 +- 15%**
**Dimension (L) = 1.0 in**

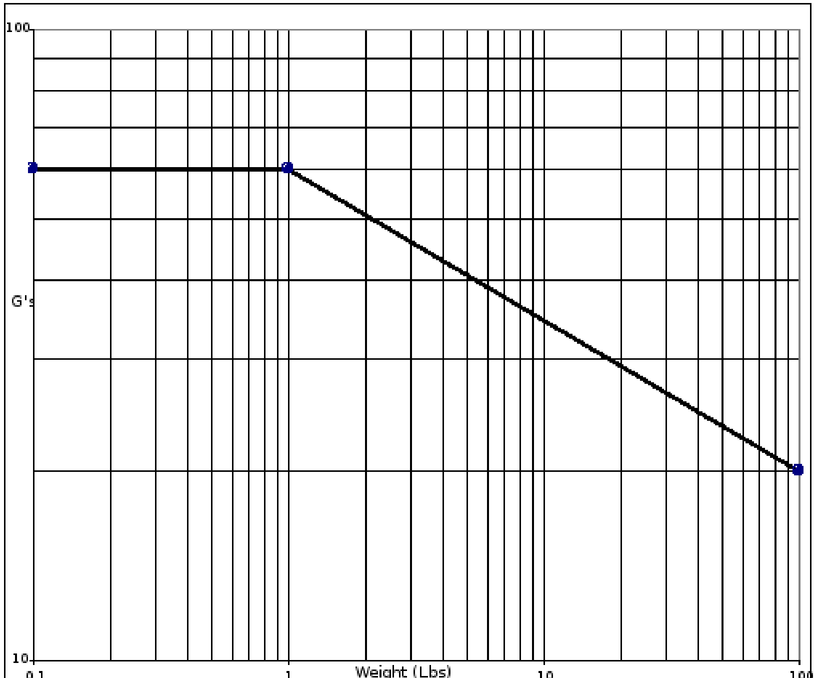
## 7425-10 LV 3712A PAF Mechanical Interface

# Backup – Mech Interfaces (2 of 2)




## 7425-10 LV 3712A PAF Mechanical Interface

# Backup – Design Loads (1 of 4)




Fame Flight Level Acceleration Environment for Cor
All Three Axes

**Design Accelerations**

| Component Wt. (Lbs) | G's |
|---|---|
| 0.1 | 60 |
| 1 | 60 |
| 100 | 20 |

**Design Acceleration Philosophy**

* These accelerations are to be used for component testin by sine burst or centrifuge,

- Apprpriate factors of safety shall be applied to these accelerations

- For designated components, the acceleration level from this curve may also be used for vibration test tailoring

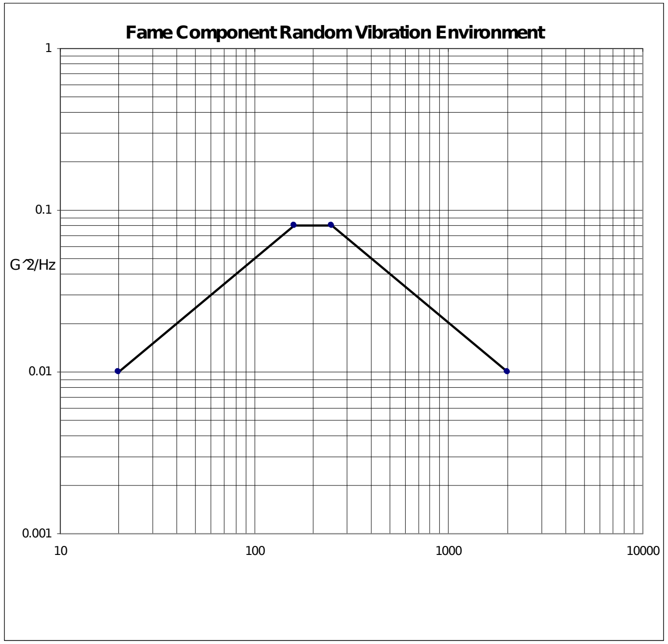
**Flight Level Mass Acceleration Curve**
**All Components, All Three Axes**

| | Flight Vehicle | | Instrument & Propellant Tank | |
|---|---|---|---|---|
| **LOAD CASE** | **Axial** | **Lateral** | **Axial** | **Lateral** |
| LV Liftoff* | +2.8 / -0.2 (TBR) | +3.5 / -3.5 (TBR) | +2.8 / -0.2 (TBR) | +10.8 / -10.8 (TBR) |
| LV MECO * | +7.0 / +0.0 (TBR) | +0.2 / -0.2 (TBR) | +7.0 / +0.0 (TBR) | +0.5 / -0.5 (TBR) |
| SC AKM Firing * | +6.3 / -0.0 (TBR) | 60 rpm | +6.3 / -0.0 (TBR) | 60 rpm |
| Handling/Transport | +2.0 / -2.0 | +2.0 / -2.0 | +2.0 / -2.0 | +2.0 / -2.0 |

*** Update Loads for New 7925-10 Design**

**Flight Level Quasi-Static**
**System & Subsystems, All Three Axes**

# Backup – Design Loads (2 of 4)




**Flight Level Environment**

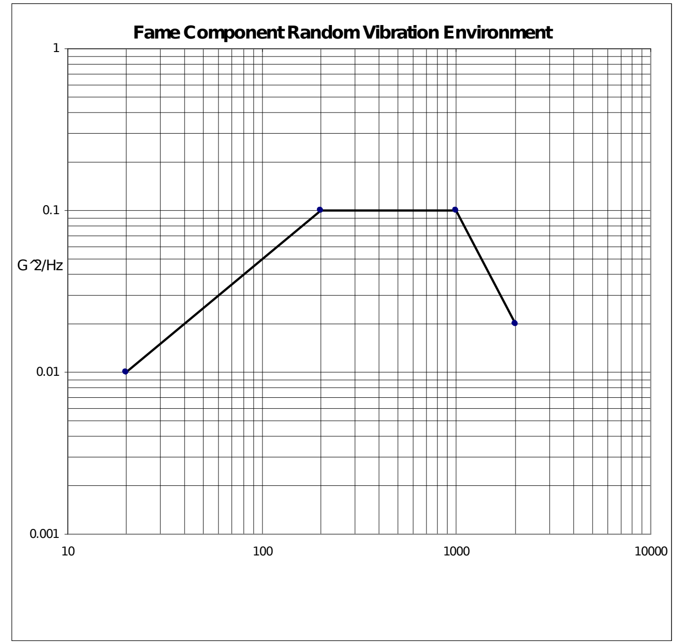
| Frequency (Hz) | G^2/Hz |
|---|---|
| 20 | 0.01 |
| 160 | 0.08 |
| 250 | 0.08 |
| 2000 | 0.01 |

7.4 Grms

**Test Levels**

| | Margin Above Flight Level (dB) | Duration (Minutes) |
|---|---|---|
| Non-Flight Prototypes (Design & Qualification Level ) | 6 | 2 |
| Flight Units ( Protoflight Acceptance Test) | 3 | 1 |

**light Level Random Vibration Bus Components on RCS Deck, All Three Axes**




**Flight Level Environment**

| Frequency (Hz) | G^2/Hz |
|---|---|
| 20 | 0.01 |
| 200 | 0.1 |
| 1000 | 0.1 |
| 2000 | 0.02 |

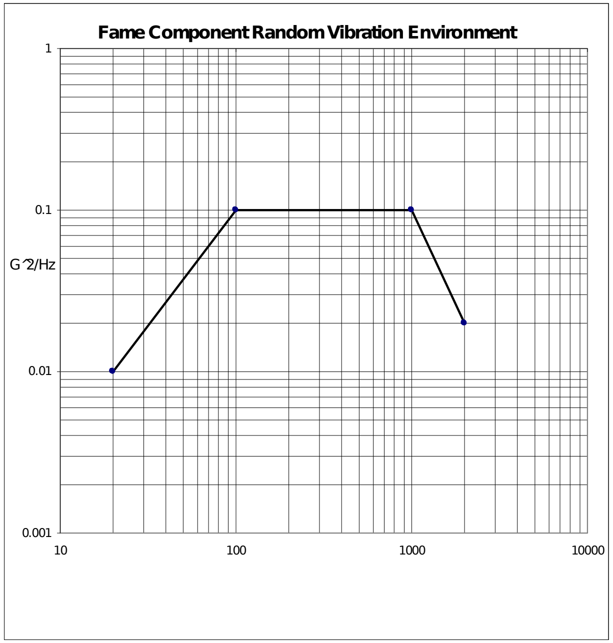
11.6 Grms

**Test Levels**

| | Margin Above Flight Level (dB) | Duration (Minutes) |
|---|---|---|
| Non-Flight Prototypes (Design & Qualification Level ) | 6 | 2 |
| Flight Units ( Protoflight Acceptance Test) | 3 | 1 |

**Flight Level Random Vibration Bus Components on Electronics Deck, All Three Axes**

# Backup – Design Loads (3 of 4)



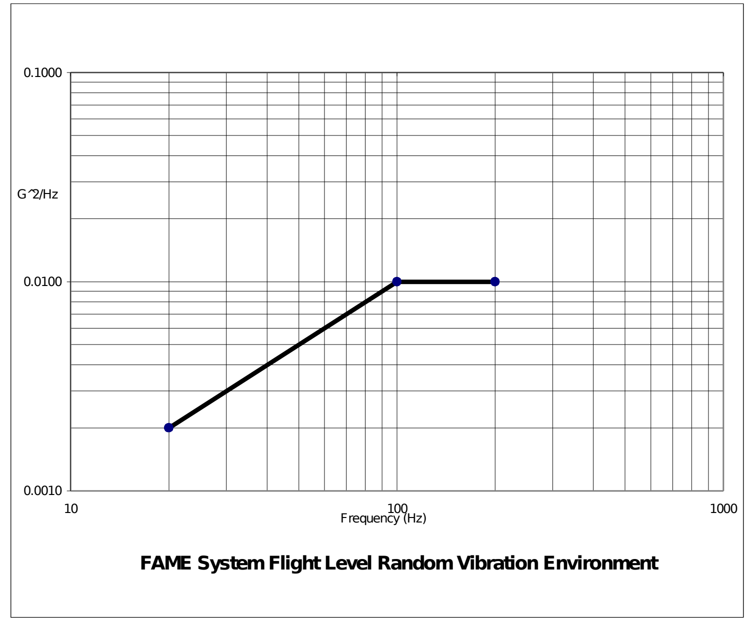

**Flight Level Environment**

| Frequency (Hz) | G^2/Hz |
|---|---|
| 20 | 0.01 |
| 100 | 0.1 |
| 1000 | 0.1 |
| 2000 | 0.02 |

11.8 Grms

**Test Levels**

| | Margin Above Flight Level (dB) | Duration (Minutes) |
|---|---|---|
| Non-Flight Prototypes (Design & Qualification Level ) | 6 | 2 |
| Flight Units ( Protoflight Acceptance Test) | 3 | 1 |




**Flight Level Environment**

1.2 Grms Overall

| Frequency (Hz) | G^2/Hz |
|---|---|
| 20 | 0.0020 |
| 100 | 0.0100 |
| 200 | 0.0100 |

All 3 Axes

**Test Level**

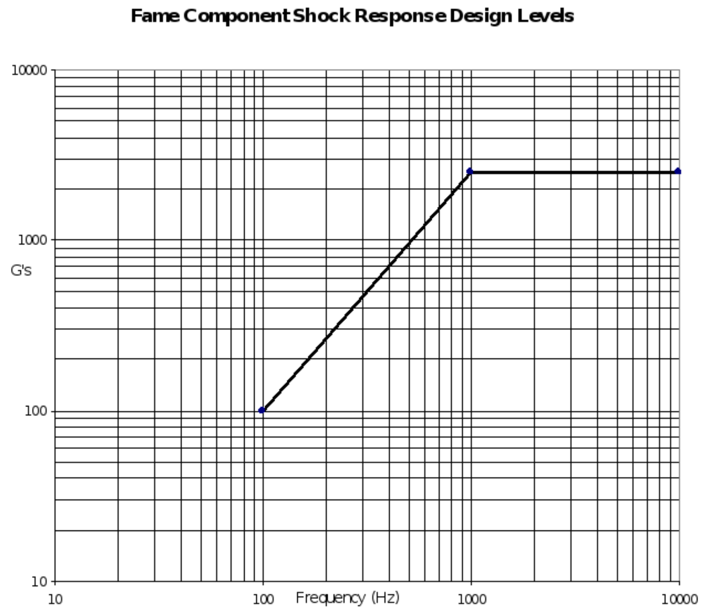
| | Margin Above Flight Level (dB) | Duration (Minutes) |
|---|---|---|
| Engineering Model (Qualification Level) | 6 | 2 |
| Flight Spacecraft ( Protoflight Acceptance ) | 3 | 2 |

Note: The Spectrum will be tailored to keep primary structural responses below Design Limit Load X 1.05

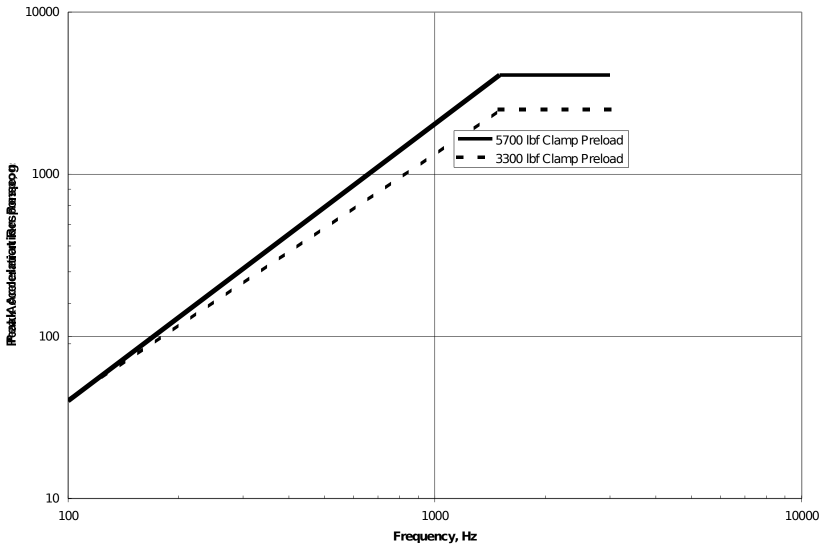
**light Level Random Vibration Bus Components on Thrust Cone, All Three Axes**

**Flight Level Random Vibration System & Subsystems, All Three Axes**

# Backup – Design Loads (4 of 4)




**Flight Level Shock Vibration**
**Bus Components, All Three Axes (Q=10)**




**Flight Level Shock Vibration**
**System, All Three Axes**

# Backup – Analysis Approach (1 of 4)

- Analysis Responsibilities
  - Conduct the Following Analyses
    - Initial Loads Analysis
    - Coupled Loads Analysis Model and LTM Preparation
    - Transportation and Handling Loads Analysis
    - Test Loads Analysis – Pre and Post
    - Detailed Stress Analysis Including Margins of Safety
    - Modal and Dynamic Analyses
    - Deflection and Deformation Analyses
  - Develop FEM Models of the Spacecraft and Flight Vehicle
  - Provide Support in Selection of Load Paths, Part Sizes, and Materials
  - Provide Support in Developing Environmental Test Plans
  - Review and Correlate the Test Data With Mathematical Models
  - Develop the Final Verified Analytical Models of the Flight Vehicle
  - Review Analyses of Vendor Supplied Components

# Backup – Analysis Approach (2 of 4)

- **Finite Element Analyses**
  - **FEM Of the FV Will Be Used to Generate Internal Loads in the Primary Structure From the Quasi-Static Design Loads, Obtain Displacements of Critical Points, and Predict Modal Frequencies and Mode Shapes**
  - **Models Will Be Reviewed Prior to Use for Correctness, Symmetry, Correct Mass Properties, Grounding, Free-Free and Constrained Modes Will Be Evaluated as Part of the Checking Process. Model Effective Weight Tables Shall Be Used to Identify Primary Modes**
  - **Results From the FEM Include Internal Loads and Grid Point Forces for Detailed Stress Analysis, Modal Frequencies, and Mode Shapes for Correlation With Modal Testing, and Nodal Deflections**

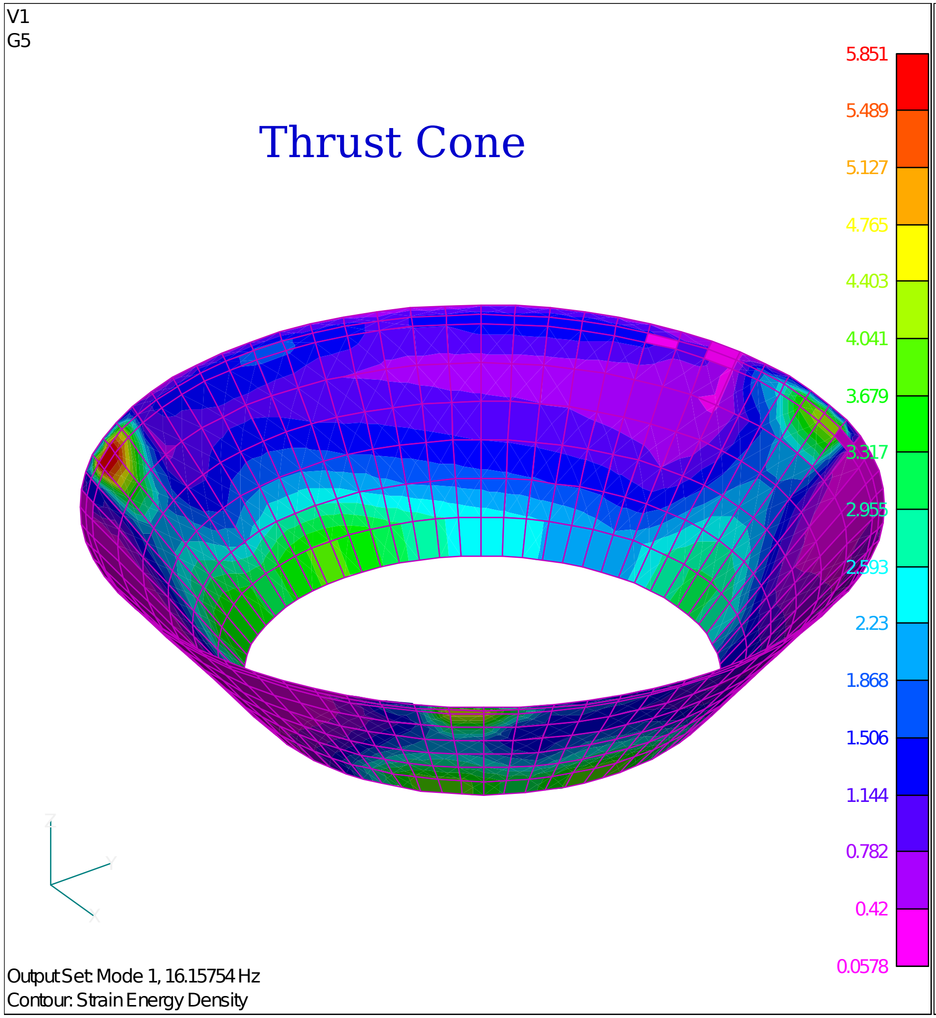
# Backup – Analysis Approach (3 of 4)

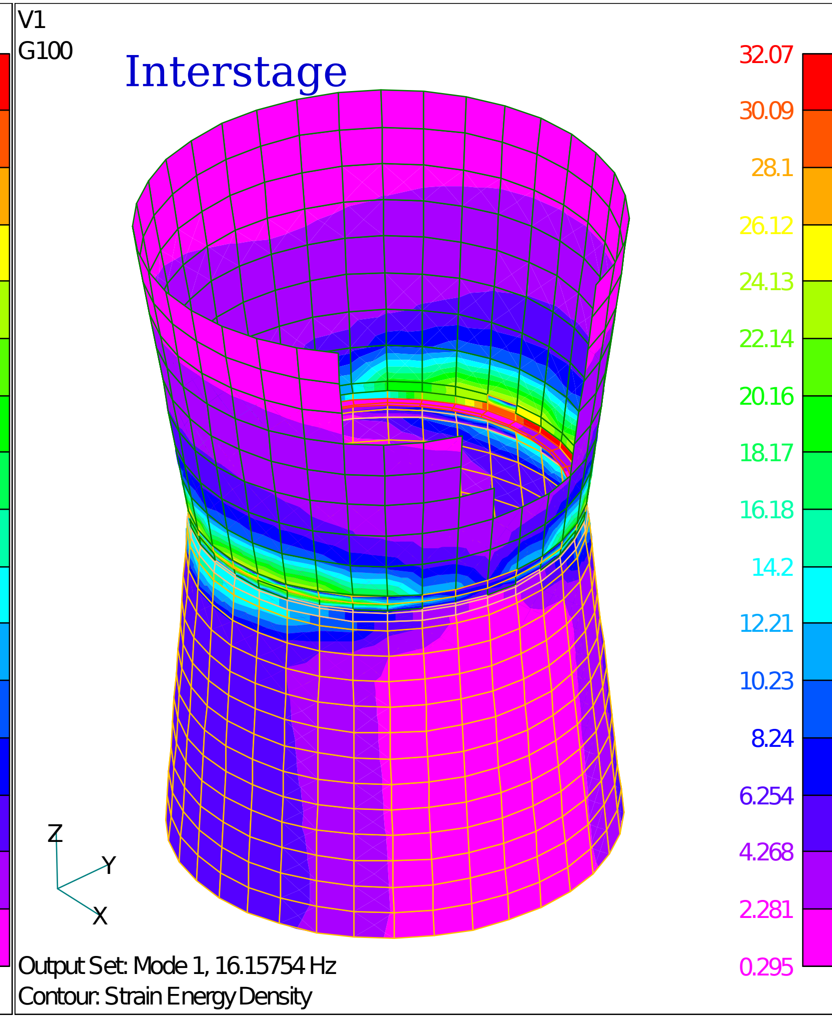
- **Detailed Stress Analyses**
  - **Detailed Stress Analysis of the Primary Structure Shall Include Strength, Local Stability, Bearing Strength, and any Other Analysis Deemed Necessary Depending on the Function of the Structural Component**
  - **Secondary Structures Shall Be Analyzed for the Effects of Test and Flight Vibro-Acoustic Test Requirements in Addition to the Quasi-Static Loads. Allowable Loads for the Structural Components Shall Be Calculated Using Standard Analysis Techniques. Secondary Structure May Be Designed Using the MAC or Quasi-Static Loads Depending on the Nature of the Structure**
  - **Global Stability of the Flight System Shall Be Analyzed As an Ultimate Failure Mode. Stability (Crippling and Component Buckling) Shall Be Analyzed in the Detail Stress Analysis. Panel Buckling Shall Be Addressed With Its Own Factor of Safety**
  - **Fasteners and Bolted Joints Shall Be Analyzed for Fastener Strength, Bearing on Components, and Strength of Fittings. Fastener Preload, Without a FOS, Shall Be Included With the Applied Load. Gapping Margins Where Necessary Shall Also Be Calculated. The Strength of the Nuts Shall Be Evaluated in Tension-Type Bolted Joints**

# Backup – Analysis Approach (4 of 4)

- **Load Cycle Program**
  - Coupled Loads Analysis (CLA) Shall Be Performed to Assure That the DLL Factors Are Adequate and That Positive Margins of Safety Are Maintained for Flight Events
  - CLA Shall Be Performed by the Launch Vehicle Dynamics Group. The Craig-Bampton Model of the FV Shall Be Coupled to the Structural Model of the LV. Forcing Functions Are Applied for Various Flight Events. The Direct Results Are then Multiplied by the FAME Supplied Transformation Matrices to Obtain Local Stresses, Loads, Accelerations, and Displacements of Concern
  - A Preliminary Design Load Cycle (PDLC), Final Design Load Cycle (FDLC), and a Verification Load Cycle (VLC) Shall Be Performed and Scheduled to Coincide With the PDR, CDR, and Verification Readiness Review (VRR)
  - PDLC and FDLC Use the FV FEM at Their Current State of Maturity. There Is No Effort Made to Correlate the Model Since Test Data Are Not Available at the Time
  - VLC Model Shall Be Correlated to Actual Structural Test Data. The Model Shall Be Modified to Match Primary Frequencies and Mode Shapes

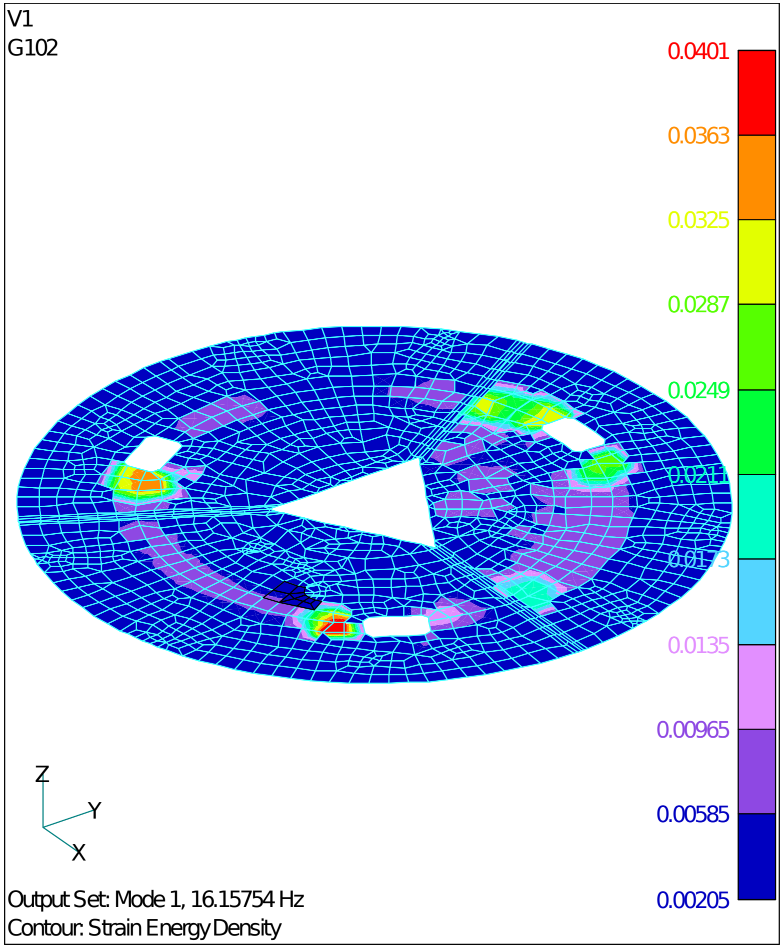
# Backup – Mechanical Analysis (1 of 6)

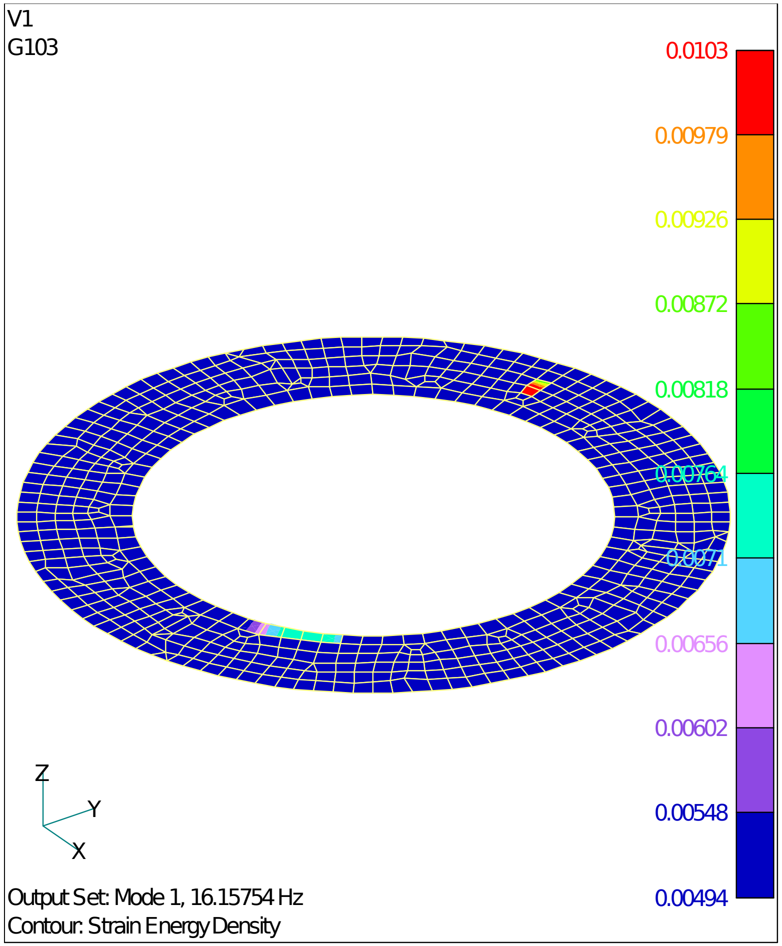



**Primary Structure Strain Energy Density**

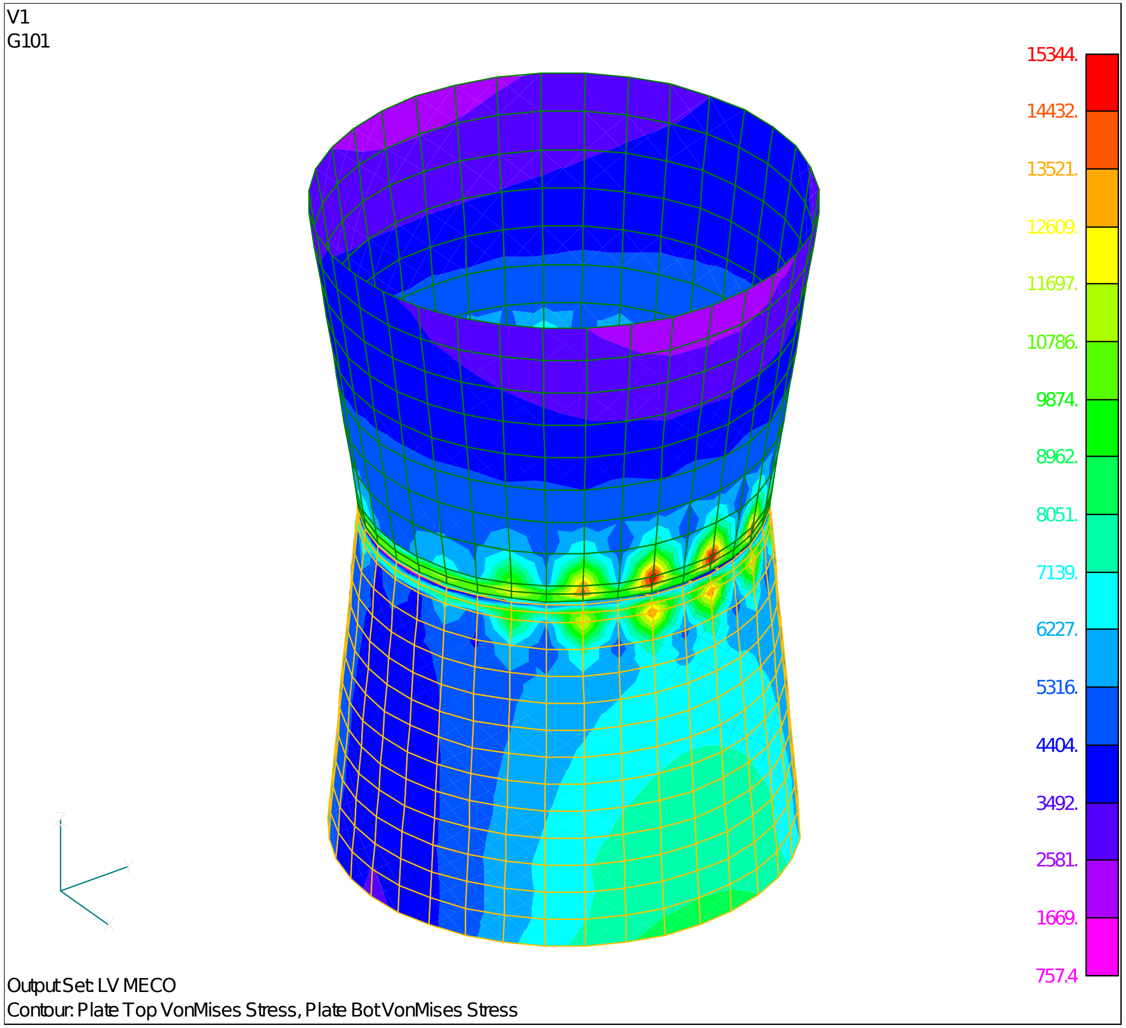
# Backup – Mechanical Analysis (2 of 6)




## Electronics Deck / Substrate Strain Energy Density

# Backup – Mechanical Analysis (3 of 6)




$f := 15334 \, psi$ Von Mises Stress

Material: Alu. 6061-T6

$Ftu := 42000 \, psi$

$Fty := 35000 \, psi$

$FS_u := 1.4$

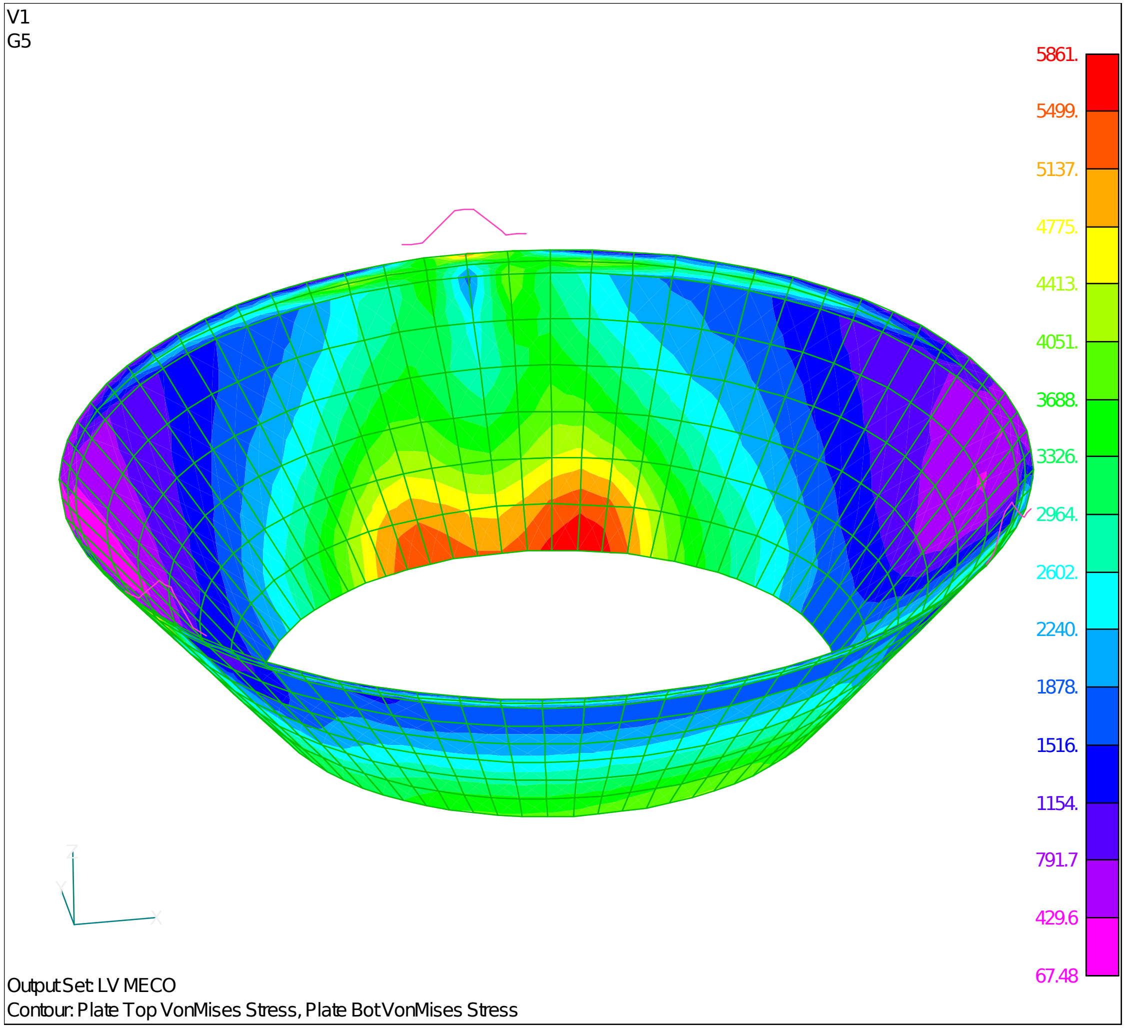
$FS_y := 1.1$

$MS_u := \frac{Ftu}{f \cdot FS_u} - 1$ $MS_u = 0.956$

$MS_y := \frac{Fty}{f \cdot FS_y} - 1$ $MS_y = 1.075$

**Interstage Primary Structure Stress Contour**

# Backup – Mechanical Analysis (4 of 6)




$f := 5861 \cdot psi$

Material: Alu. 6061-T6

$Ftu = 42000 \cdot psi$

$Fty = 35000 \cdot psi$

$FS_u := 1.4$

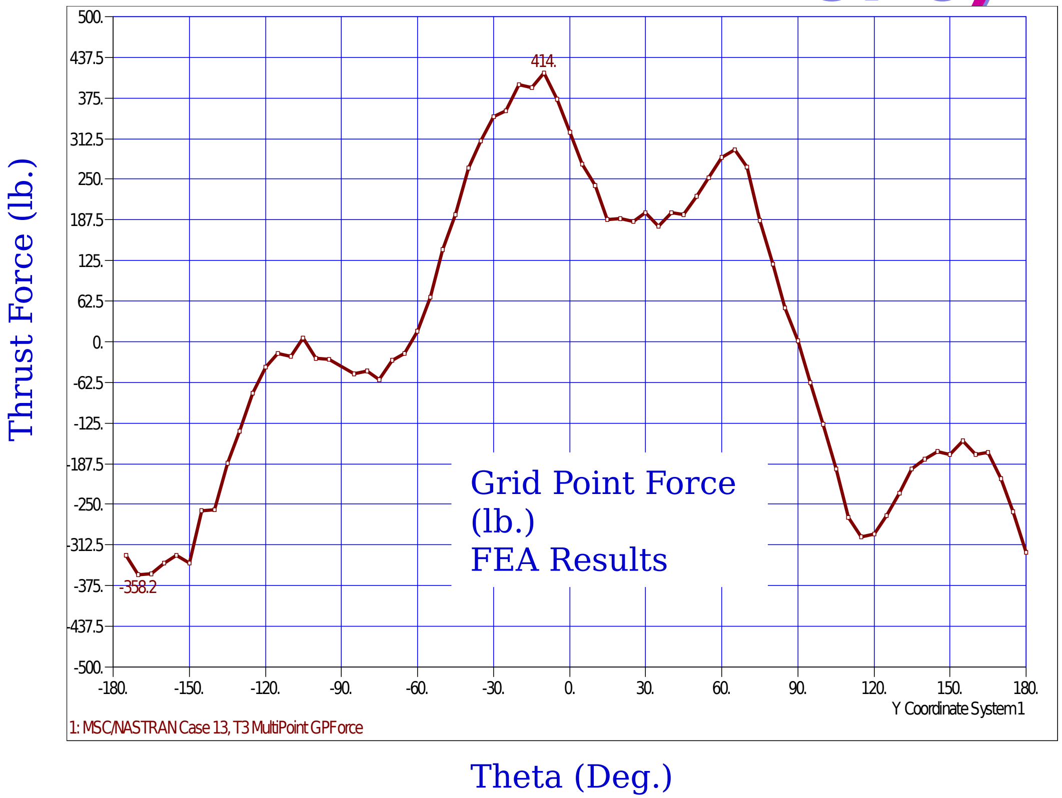
$FS_y := 1.1$

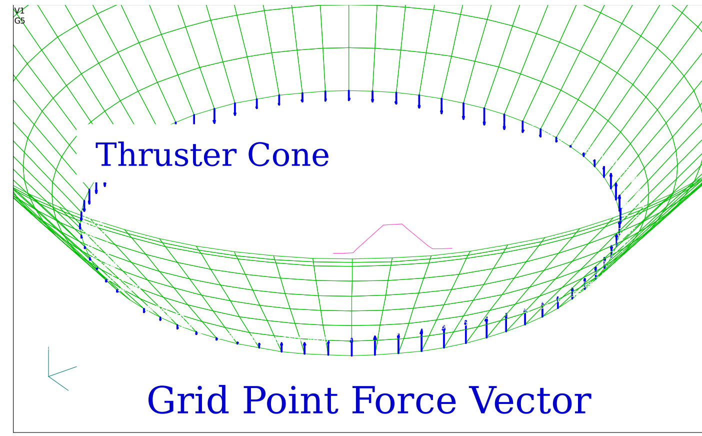
$MS_u := \frac{Ftu}{f \cdot FS_u} - 1 \qquad MS_u = 4.119$

$MS_y := \frac{Fty}{f \cdot FS_y} - 1 \qquad MS_y = 4.429$

## SC Bus Primary Structure Stress Contour

# Backup – Mechanical Analysis (5 of 6)




Load Case: LV MECO

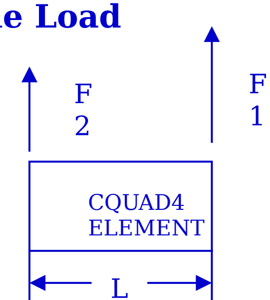
Calculated Peak Line Load:
FEA: 224 lb./in
Analytical: 213 lb./in

**Analytical Peak line Load** **FEA Peak line Load**

$$T_{analytical} = \frac{F_a}{2\pi R} + \frac{M}{\pi R^2}$$

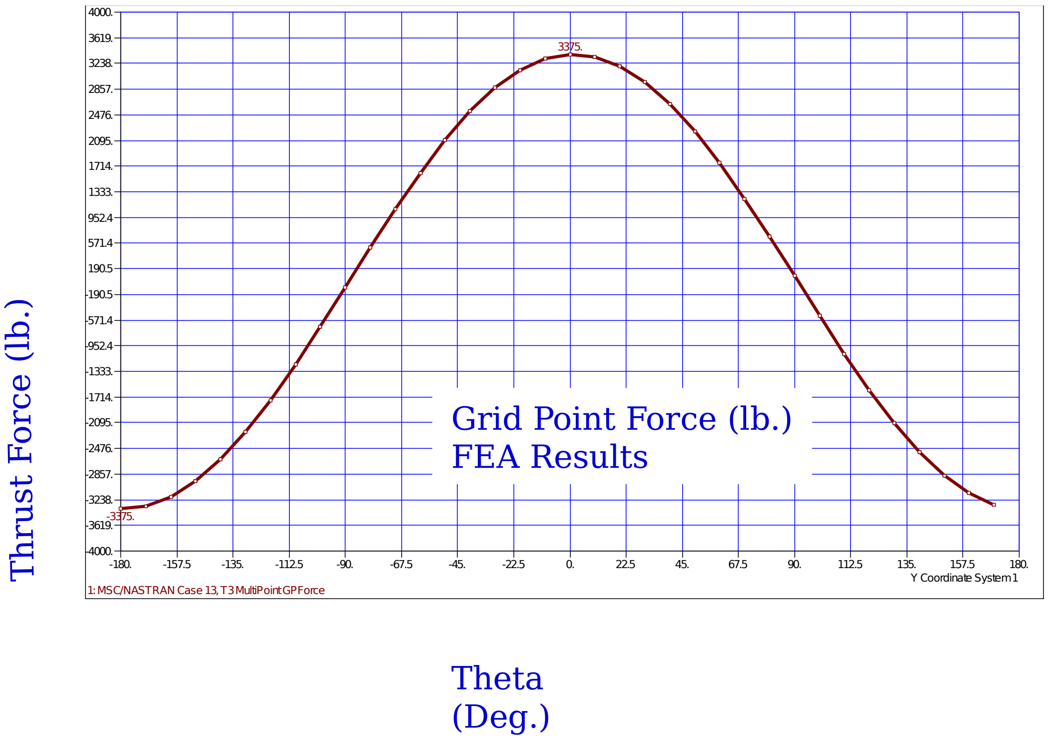
$$F_{avg} = \frac{F_1 + F_2}{2}$$

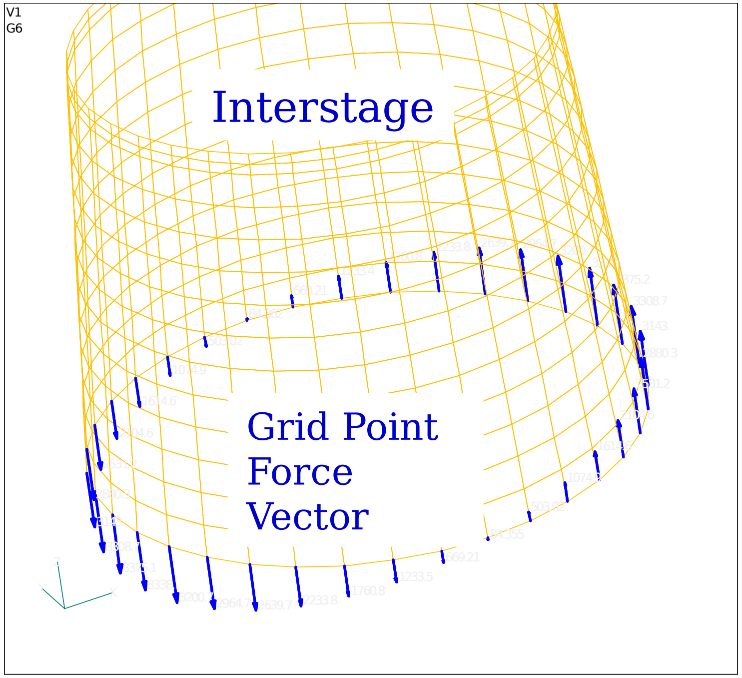
$$T_{fea} = \frac{F_{avg}}{L}$$




## Observatory Marmon Clamp Line Loads

# Backup – Mechanical Analysis (6 of 6)




Load Case: LV MECO

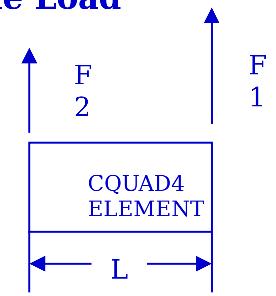
**Analytical Peak line Load**

$$T_{analytical} = \frac{F_a}{2\pi R} + \frac{M}{\pi R^2}$$

**FEA Peak line Load**

$$F_{avg} = \frac{F_1 + F_2}{2}$$

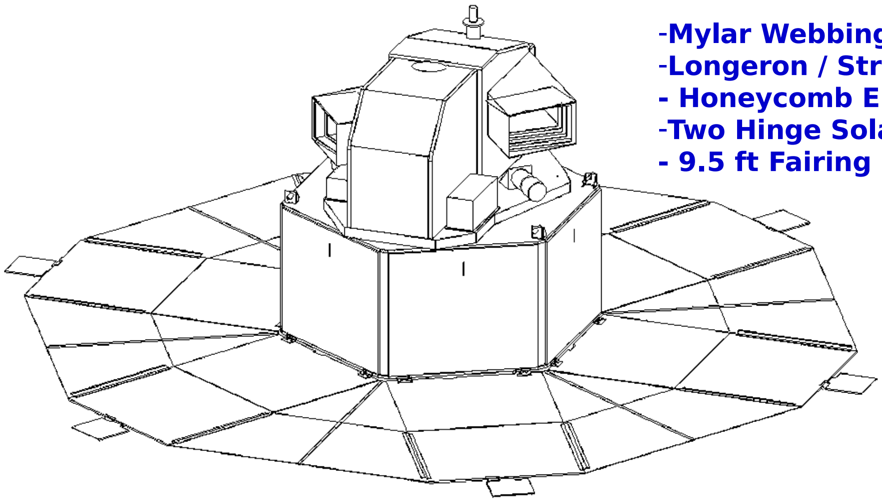
$$T_{fea} = \frac{F_{avg}}{L}$$




Calculated Line Load:
FEA: 1038 lb./in
Analytical: 1065 lb./in

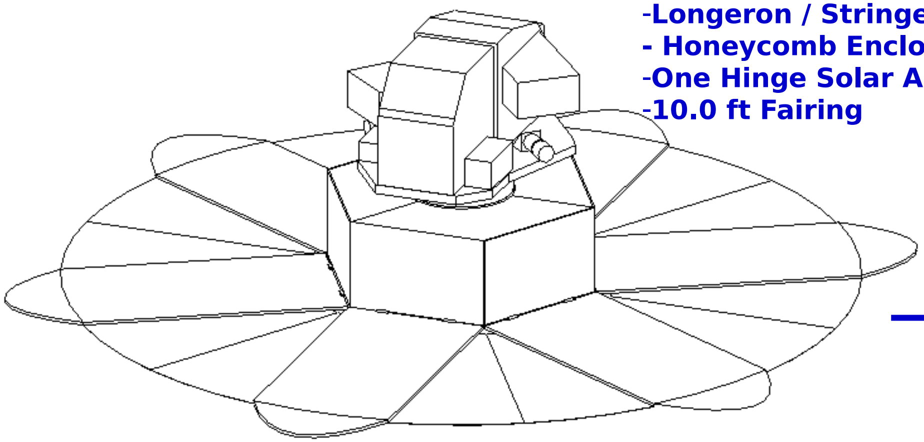
## Flight Vehicle Marmon Clamp Line Loads

# Backup – Design Evolution



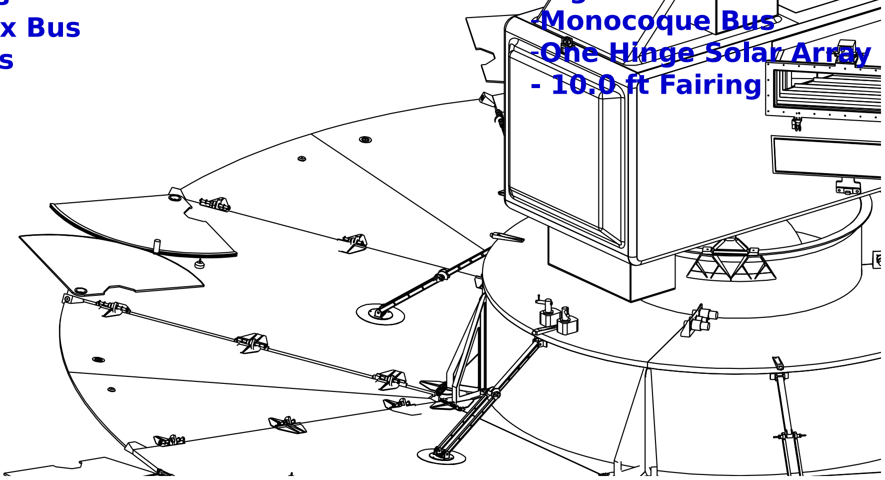
-Mylar Webbing Sun Shades
-Longeron / Stringer Hex Bus
- Honeycomb Enclosures
-Two Hinge Solar Array
- 9.5 ft Fairing

## CSR Design Layout



-Rigid Panel Sun Shades
-Longeron / Stringer Hex Bus
- Honeycomb Enclosures
-One Hinge Solar Array
-10.0 ft Fairing

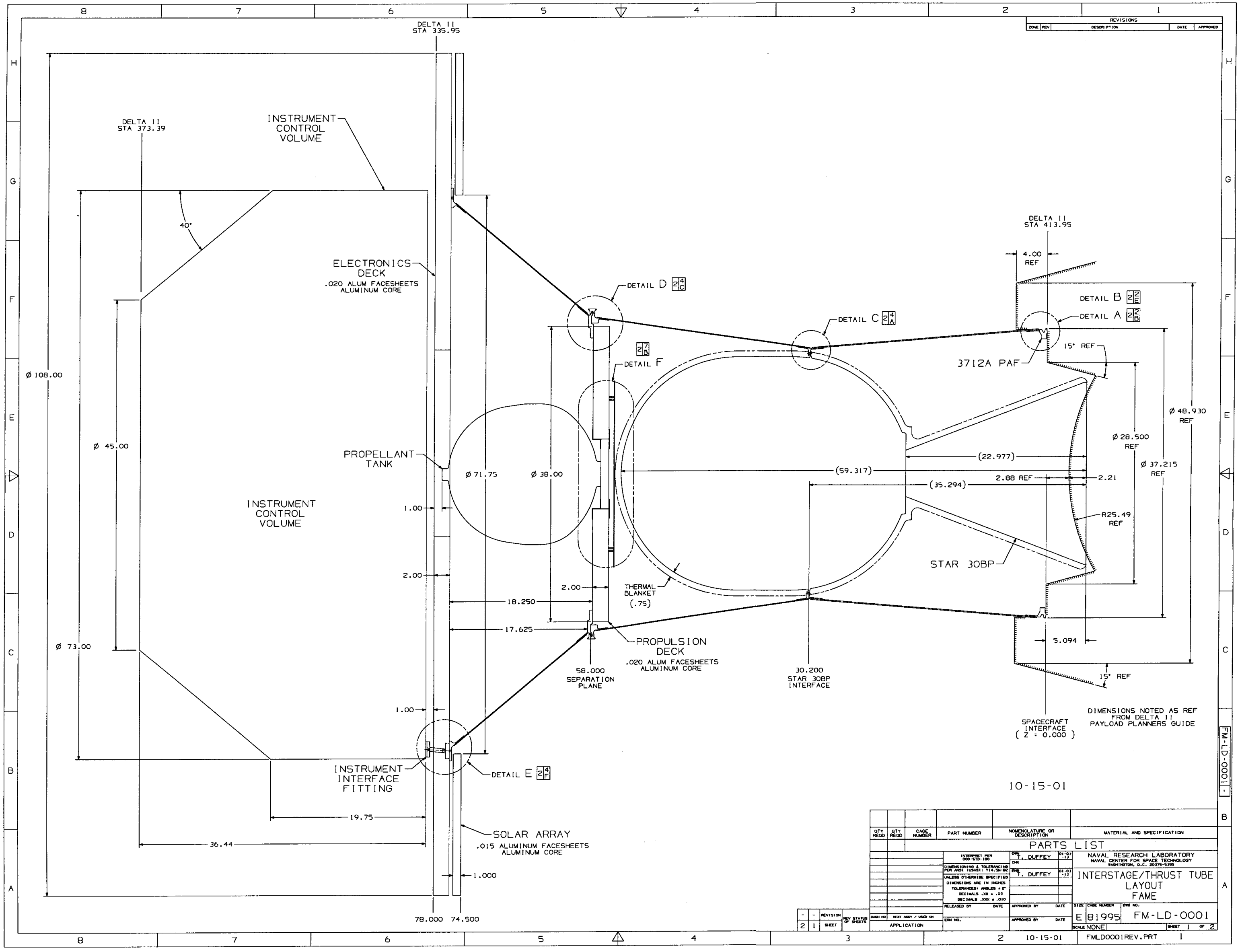
## 10/2000 Design Layout



-Rigid Panel Sun Shades
-Monocoque Bus
-One Hinge Solar Array
- 10.0 ft Fairing

## 6/2001 Design Layout

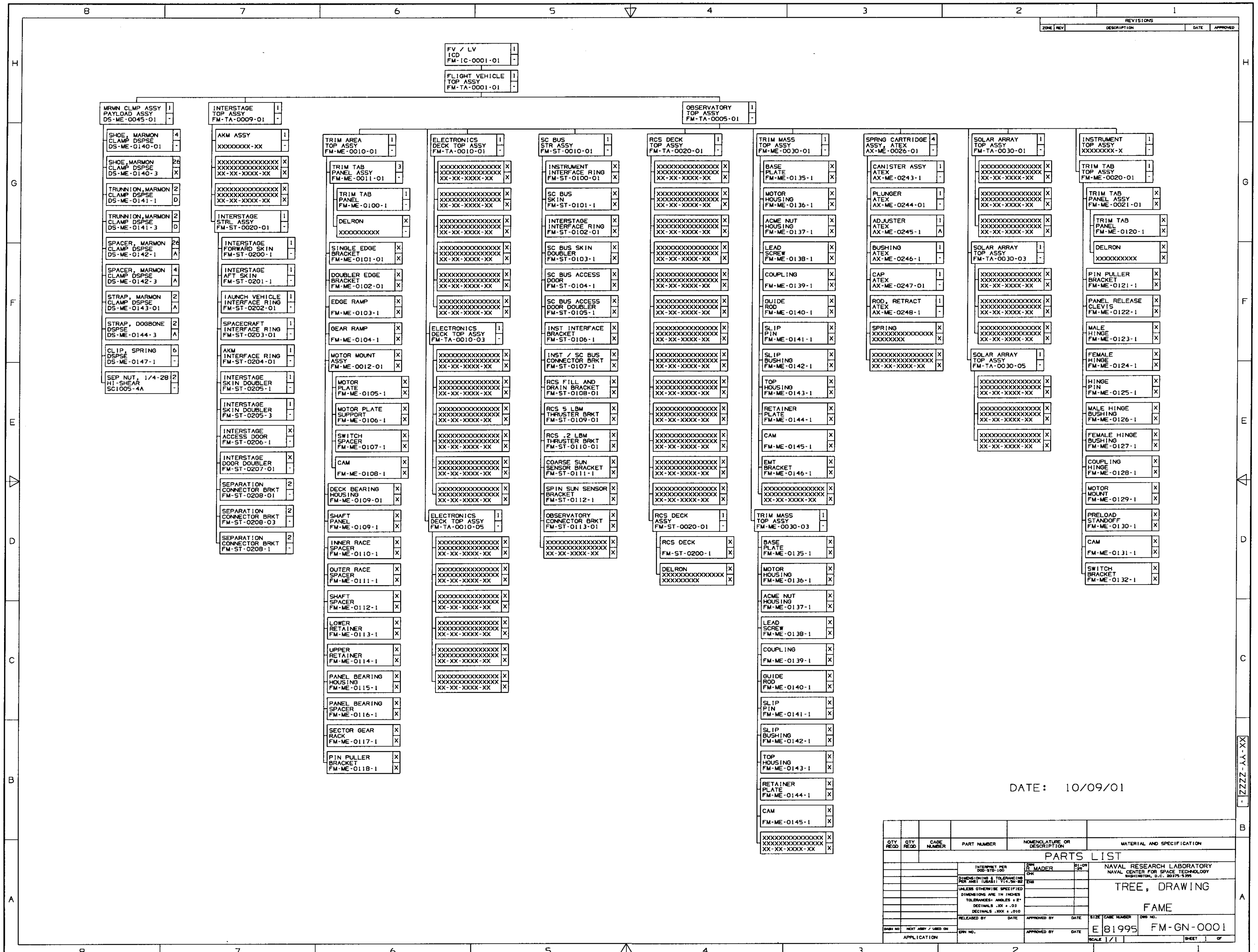
# Backup – FV Dimensions



# Backup – Material List

- Spacecraft Bus Structural Assy
  - Skin: .090 Thick 7075-T7351 Aluminum Sheet IAW QQ-A-250/12
  - Interface Rings: 3.0 Thick 7075-T7351 Aluminum Plate IAW QQ-A-250/12
  - Electronics Deck: 2.0 Thick Sandwich Panel, .015 Thick 6061-T6 Al Face Sheet and 1/8 Hex-5052 .0007 3.1 lbm/cu ft Core
  - Solar Array Substrate: 1.0 Thick Sandwich Panel, 4 X .005 Thick M55J/RS3 Uni-Tape and 1/8 Hex-5052 .0007 3.1 lbm/cu ft Core
  - RCS Deck: 2.0 Thick Sandwich Panel, .015 Thick 6061-T6 Al Face Sheet and 1/8 Hex-5052 .0007 3.1 lbm/cu ft Core
  - Miscellaneous Bracketry: 7075-T7351 Aluminum Plate IAW QQ-A-250/12 and 6061-T6 Aluminum Sheet IAW QQ-A-250/11
- Interstage Structural Assy
  - Skin: .090 and .125 Thick 7075-T7351 Aluminum Sheet IAW QQ-A-250/12
  - Interface Rings: 3.0 Thick 7075-T7351 Aluminum Plate IAW QQ-A-250/12
  - Miscellaneous Bracketry: 7075-T7351 Aluminum Plate IAW QQ-A-250/12 and 6061-T6 Aluminum Sheet IAW QQ-A-250/11

# Backup – Drawing Tree




tree_dwg.tif

# Backup – Mass Report (1 of 3)

**FAME MASS PROPERTIES REPORT (English Units)** **VERSION: 10/16/2001**

| SUBSYSTEM COMPONENT | QTY | | TOTAL MASS (lbm) | UNCERT MASS (%) | MASS (lbm) | CENTER OF MASS | | | INERTIA ABOUT CENTER OF MASS | | | | | | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $X_b$ cg (in) | $Y_b$ cg (in) | $Z_b$ cg (in) | $Ixx_b$ (lbm*in^2) | $Iyy_b$ (lbm*in^2) | $Izz_b$ (lbm*in^2) | $Pxz_b$ (lbm*in^2) | $Pyz_b$ (lbm*in^2) | $Pxy_b$ (lbm*in^2) | |
| **FLIGHT VEHICLE, STOWED, WET** | | | 2476.88 | 4% | 2374.52 | -0.06 | 0.21 | 58.06 | 2,389,918 | 2,296,896 | 1,151,785 | 5,756 | 20,061 | 42,773 | |
| **SPACECRAFT, DEPLOYED, WET** | | | 1227.46 | 7% | 1146.26 | -0.11 | 0.43 | 81.36 | 727,754 | 635,009 | 879,274 | 9,407 | 8,242 | 42,806 | |
| **INSTRUMENT SUBSYSTEM** | | | 537.40 | 1% | 533.23 | 0.09 | 0.03 | 95.29 | NA | NA | NA | NA | NA | NA | |
| - *INSTRUMENT ASSY, WITH STAR TRACKER ASSY* | *1* | *x* | *512.40* | *0%* | *512.40* | *0.10* | *0.10* | *95.20* | *254463.00* | *141665.00* | *332758.00* | *7387.00* | *13494.00* | *54126.00* | *MASS PROPERTIES FROM LOCKHEED, 10/12/01* |
| - *GOVERNMENT FURNISHED EQUIPMENT* | *1* | *x* | *25.00* | *20%* | *20.83* | *-0.09* | *-1.30* | *97.10* | *9809.00* | *12381.00* | *17661.00* | *-973.00* | *-1239.00* | *-7495.00* | *MASS PROPERTIES FROM LOCKHEED, 10/12/01* |
| **STRUCTURAL SUBSYSTEM** | | | 230.76 | 12% | 206.45 | -0.01 | -0.02 | 71.07 | NA | NA | NA | NA | NA | NA | |
| THRUST CONE MARMON CLAMP RING | 1 | x | 12.12 | 10% | 11.02 | 0.00 | 0.00 | 58.18 | 2113.96 | 2113.96 | 4223.11 | 0.00 | 0.00 | 0.00 | CAD MODEL(.125 THK AL), 09/17/01 |
| THRUST CONE SKIN | 1 | x | 37.23 | 10% | 33.85 | 0.00 | 0.00 | 67.67 | 14637.07 | 14637.07 | 27701.96 | 0.00 | -13.47 | 0.00 | CAD MODEL(.090 THK AL), 09/13/01 |
| THRUST CONE TOP RING | 1 | x | 18.14 | 10% | 16.49 | 0.00 | 0.00 | 75.65 | 10195.29 | 10195.29 | 20383.17 | 0.00 | 0.00 | 0.00 | CAD MODEL(.250 BY .125 THK AL), 09/17/01 |
| THRUST CONE SKIN DOUBLER | 2 | x | 1.50 | 10% | 1.36 | 0.00 | 0.00 | 67.67 | 550.84 | 550.84 | 1035.76 | 0.00 | 0.00 | -517.17 | CAD MODEL(.090 THK AL), 07/20/01 |
| THRUST CONE ACCESS DOUBLER | 4 | x | 3.60 | 20% | 3.00 | 0.00 | 0.00 | 70.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| ELECTRONICS DECK | 3 | x | 71.57 | 10% | 65.06 | 0.00 | 0.00 | 77.00 | 61118.95 | 61118.95 | 122184.00 | 0.00 | 0.00 | 0.00 | CAD MODEL(2.00 INCH THK WITH .015 INCH AL F.S.), 09/18/01 |
| ELECTRONICS DECK DOUBLER | 3 | x | 1.65 | 10% | 1.50 | -1.02 | 0.00 | 77.00 | 750.00 | 700.00 | 1500.00 | 0.00 | 0.00 | 0.00 | CAD MODEL(.040 THK AL), 09/14/01 |
| PROPELLANT TANK SUPPORT BRACKET | 1 | x | 4.15 | 10% | 3.78 | 0.00 | 0.00 | 77.96 | 95.48 | 95.48 | 190.79 | 0.00 | 0.00 | 0.00 | CAD MODEL(.050 THK AL), 09/14/01 |
| SOLAR ARRAY SUBSTRATE | 3 | x | 21.53 | 10% | 19.57 | 0.00 | 0.00 | 75.00 | 30651.30 | 30651.30 | 61297.79 | 0.00 | 0.00 | 0.00 | CAD MODEL(1.00 INCH WITH .020 INCH COMPOSITE F.S.), 09/18/01 |
| SOLAR ARRAY STANDOFF | 24 | x | 0.68 | 20% | 0.57 | 0.00 | 0.00 | 75.75 | 588.79 | 588.79 | 1177.56 | 0.00 | 0.00 | 0.00 | CAD MODEL(.50 INCH G-10), 09/14/01 |
| ANTENNA BRACKET, SC LATERAL | 2 | x | 0.76 | 10% | 0.69 | 0.00 | 0.00 | 79.91 | 4.70 | 1798.50 | 1799.95 | 0.00 | 0.00 | 0.00 | CAD MODEL(.063 THK AL), 09/14/01 |
| THRUSTER BRACKET, .2 LBF FORCE | 6 | x | 0.86 | 10% | 0.78 | 0.00 | 0.00 | 64.50 | 27.62 | 589.09 | 563.77 | 0.00 | 0.00 | 0.00 | UPDATE |
| THRUSTER BRACKET, 5 LBF FORCE | 2 | x | 0.41 | 10% | 0.37 | 0.00 | 0.00 | 71.50 | 366.19 | 0.00 | 366.19 | 0.00 | 0.00 | 0.00 | UPDATE |
| SEPARATION CONNECTOR PLATE | 2 | x | 0.10 | 10% | 0.09 | 0.00 | 0.00 | 56.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| PROPELLANT SERVICE PLATE | 1 | x | 0.23 | 10% | 0.21 | 0.00 | -18.00 | 65.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| INSTRUMENT SUPPORT BRACKET | 3 | x | 5.40 | 20% | 4.50 | 0.00 | 0.00 | 75.00 | 3000.00 | 3000.00 | 6000.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| RCS DECK | 1 | x | 8.93 | 10% | 8.12 | 0.00 | 0.00 | 56.75 | 958.36 | 958.36 | 1910.04 | 0.00 | 0.00 | 0.00 | CAD MODEL(2.00 INCH WITH .015 INCH AL F.S.), 09/18/01 |
| TANK SUPPORT BRACKET | 1 | x | 1.24 | 20% | 1.03 | 0.00 | 0.00 | 56.66 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| TANK SUPPORT DECK | 1 | x | 1.07 | 10% | 0.97 | 0.00 | 0.00 | 56.25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | CAD MODEL(1.00 INCH THK WITH .050 INCH AL F.S.), 09/18/01 |
| COARSE SUN SENSOR BRACKET | 5 | x | 0.60 | 20% | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| BALLAST MASS, INERTIA RATIO | 1 | x | 0.00 | 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| BALANCE MASS 1, COUPLE BALANCE | 1 | x | 1.50 | 0% | 1.50 | 0.00 | 0.00 | 60.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| BALANCE MASS 2, COUPLE BALANCE | 1 | x | 1.50 | 0% | 1.50 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| MISCELLANEOUS MASS, FASTENERS | 1 | x | 36.00 | 20% | 30.00 | 0.00 | 0.00 | 67.00 | 15000.00 | 15000.00 | 15000.00 | 0.00 | 0.00 | 0.00 | MASS FROM MADER, 07/06/01 |
| **RCS SUBSYSTEM** | | | 162.80 | 19% | 137.25 | -0.01 | 0.01 | 65.10 | NA | NA | NA | NA | NA | NA | |
| PROPELLANT, HYDRAZINE | 1 | x | 110.00 | 25% | 88.00 | 0.00 | 0.00 | 65.95 | 2543.20 | 2543.20 | 2543.20 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 09/09/01 - INERTIAS FROM CAD, 09/17/01 |
| PROPELLANT TANK | 1 | x | 16.80 | 5% | 16.00 | 0.00 | 0.00 | 66.43 | 585.47 | 585.47 | 554.45 | 0.00 | 0.00 | 0.00 | MASS FROM CLEMENTINE MASS REPORT, 09/11/01 |
| PRESSURANT | 1 | x | 0.22 | 10% | 0.20 | -10.00 | 10.00 | 65.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 09/18/01 |
| PRESSURANT TANK | 5 | x | 10.61 | 5% | 10.10 | 0.00 | 0.00 | 62.28 | 49.53 | 49.53 | 49.53 | 0.00 | 0.00 | 0.00 | UPDATE |
| PRESSURANT TANK SUPPORT | 1 | x | 4.40 | 10% | 4.00 | 0.00 | 0.00 | 62.28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | UPDATE |
| THRUSTER, 5 LBM FORCE | 2 | x | 3.15 | 5% | 3.00 | 0.00 | 0.00 | 71.50 | 1521.68 | 0.67 | 1521.21 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 - INERTIAS FROM CAD, 07/20/01 |
| THRUSTER, .2 LBM FORCE | 6 | x | 4.73 | 5% | 4.50 | 0.00 | 0.00 | 64.50 | 176.30 | 3959.75 | 3795.88 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 - INERTIAS FROM CAD, 07/20/01 |
| PROPELLANT LINE | 1 | x | 4.80 | 20% | 4.00 | 0.00 | 0.00 | 58.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 |
| PROPELLANT LINE CLAMP | 45 | x | 0.54 | 20% | 0.45 | 0.00 | 0.00 | 58.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 |
| PROPELLANT LINE STANDOFF | 45 | x | 0.60 | 20% | 0.50 | 0.00 | 0.00 | 58.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 |
| PROPELLANT FILL VALVE | 3 | x | 0.95 | 5% | 0.90 | 0.00 | 0.00 | 58.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 |

# Backup – Mass Report (2 of 3)

**FAME MASS PROPERTIES REPORT (English Units)** **VERSION: 10/16/2001**

| SUBSYSTEM COMPONENT | QTY | | TOTAL MASS (lbm) | UNCERT MASS (%) | MASS (lbm) | CENTER OF MASS $X_b$ cg (in) | $Y_b$ cg (in) | $Z_b$ cg (in) | INERTIA ABOUT CENTER OF MASS $Ixx_b$ (lbm*in^2) | $Iyy_b$ (lbm*in^2) | $Izz_b$ (lbm*in^2) | $Pxz_b$ (lbm*in^2) | $Pyz_b$ (lbm*in^2) | $Pxy_b$ (lbm*in^2) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ADCS SUBSYSTEM** | | | **21.25** | **5%** | **20.24** | **-8.55** | **1.88** | **74.16** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| IMU W/O SHIELDING | 2 | x | 3.48 | 5% | 3.31 | 19.76 | 5.04 | 73.34 | 13.87 | 68.41 | 64.03 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| SPIN SUN SENSOR | 2 | x | 0.74 | 5% | 0.70 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| SPIN SUN SENSOR ELECTRONICS | 2 | x | 2.52 | 5% | 2.40 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| COARSE SUN SENSOR | 10 | x | 0.26 | 5% | 0.25 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| EMT (30 Am^2) | 3 | x | 6.28 | 5% | 5.98 | -15.52 | -9.93 | 72.62 | 1444.57 | 1254.14 | 2399.25 | 20.09 | -156.66 | -825.10 | MASS FROM DELAHUNT, 09/25/01 |
| MAGNETOMETER-103 | 2 | x | 1.05 | 5% | 1.00 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| STDPU/CABLES | 2 | x | 6.93 | 5% | 6.60 | -22.08 | 12.24 | 75.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM DELAHUNT, 09/25/01 |
| **MECHANISM SUBSYSTEM (2)** | | | **51.08** | **9%** | **46.76** | **-4.30** | **-4.30** | **71.79** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| *TRIM-TAB PANEL* | *3* | *x* | *2.67* | *10%* | *2.43* | *0.00* | *0.00* | *79.14* | *3287.83* | *3287.83* | *6575.55* | *0.00* | *0.00* | *0.00* | *MASS FROM WHALEN, 10/15/01* |
| *TRIM-TAB HINGE ASSY* | *3* | *x* | *3.61* | *10%* | *3.28* | *0.00* | *0.00* | *78.46* | *2243.79* | *2243.79* | *4487.26* | *0.00* | *0.00* | *0.00* | *MASS FROM WHALEN, 10/15/01* |
| *TRIM-TAB MOTOR* | *3* | *x* | *2.76* | *5%* | *2.63* | *0.00* | *0.00* | *78.65* | *3623.60* | *3623.60* | *7246.87* | *0.00* | *0.00* | *0.00* | *MASS FROM KOSS, 06/20/01* |
| *TRIM-AREA PANEL* | *3* | *x* | *3.83* | *10%* | *3.49* | *0.00* | *0.00* | *78.81* | *5146.16* | *5146.16* | *10292.28* | *0.00* | *0.00* | *0.00* | *MASS FROM WHALEN, 10/15/01* |
| *TRIM-AREA HINGE ASSY* | *3* | *x* | *9.74* | *10%* | *8.86* | *0.00* | *0.00* | *77.91* | *2500.00* | *2500.00* | *4500.00* | *0.00* | *0.00* | *0.00* | *MASS FROM WHALEN, 10/15/01* |
| *TRIM-AREA MOTOR* | *3* | *x* | *2.76* | *5%* | *2.63* | *0.00* | *0.00* | *73.57* | *1500.00* | *1500.00* | *2500.00* | *0.00* | *0.00* | *0.00* | *MASS FROM KOSS, 06/20/01* |
| *TRIM-MASS MASS* | *2* | *x* | *11.00* | *10%* | *10.00* | *-9.63* | *-9.63* | *66.76* | *1151.06* | *1151.06* | *2299.81* | *0.00* | *0.00* | *1624.45* | *MASS FROM GATES, 09/26/01* |
| *TRIM-MASS SUPPORT ASSY* | *2* | *x* | *9.90* | *10%* | *9.00* | *-9.68* | *-9.68* | *67.86* | *885.06* | *885.06* | *1362.24* | *0.00* | *0.00* | *397.19* | *MASS FROM WHALEN, 10/15/01* |
| *TRIM-MASS MOTOR* | *2* | *x* | *1.84* | *5%* | *1.75* | *-9.63* | *-9.63* | *61.60* | *200.00* | *300.00* | *500.00* | *0.00* | *0.00* | *0.00* | *MASS FROM KOSS, 06/20/01* |
| *KICKOFF CANNISTER ASSY* | *4* | *x* | *2.97* | *10%* | *2.70* | *0.00* | *0.00* | *58.00* | *350.00* | *350.00* | *650.00* | *0.00* | *0.00* | *0.00* | *MASS FROM WHALEN, 10/15/01* |
| **EPS SUBSYSTEM (2)** | | | **116.14** | **12%** | **103.40** | **-2.47** | **11.72** | **73.15** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| SOLAR CELL AND WIRING | 6 | x | 12.96 | 20% | 10.80 | 0.00 | 0.00 | 74.00 | 18056.48 | 18056.48 | 36110.13 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/25/01 |
| BATTERY, LITHIUM ION | 1 | x | 19.32 | 5% | 18.40 | -17.06 | 19.62 | 72.96 | 85.45 | 80.36 | 67.89 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/25/01 |
| PDU | 1 | x | 21.65 | 10% | 19.68 | 13.01 | 18.58 | 71.79 | 157.35 | 159.68 | 166.09 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/25/01 |
| PCU | 1 | x | 24.55 | 10% | 22.32 | -1.98 | 22.61 | 71.54 | 174.92 | 209.57 | 204.38 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/26/01 |
| SAJB | 1 | x | 1.85 | 10% | 1.68 | 21.83 | 13.12 | 74.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/26/01 |
| BCB | 1 | x | 8.98 | 10% | 8.16 | -25.75 | 0.00 | 74.05 | 48.35 | 48.35 | 77.30 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/25/01 |
| TOTAL SC BUS WIRE HARNESS | 1 | x | 26.83 | 20% | 22.36 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM RUTH, 09/25/01 |
| **RF SUBSYSTEM** | | | **27.99** | **9%** | **25.59** | **3.74** | **-9.50** | **74.16** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| TRANSPONDER | 2 | x | 10.50 | 5% | 10.00 | 5.90 | -18.90 | 75.04 | 323.24 | 103.43 | 419.30 | 0.00 | 0.00 | 85.00 | MASS FROM GARNER, 06/15/01 - INERTIAS FROM CAD, 09/21/01 |
| DIPLEXER | 2 | x | 3.14 | 5% | 2.99 | 13.63 | -21.48 | 74.75 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM GARNER, 06/15/01 - INERTIAS FROM CAD, 09/21/01 |
| HYBRID / COUPLER | 2 | x | 0.17 | 5% | 0.16 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 |
| ANTENNA, LATERAL | 2 | x | 4.40 | 10% | 4.00 | 0.00 | 0.00 | 80.25 | 7.70 | 11328.02 | 11328.02 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 - INERTIAS FROM CAD, 09/14/01 |
| ANTENNA, SC AXIAL | 1 | x | 2.20 | 10% | 2.00 | 0.00 | 0.00 | 54.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 |
| XFER SWITCHES | 3 | x | 0.79 | 5% | 0.75 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 |
| SPDT SWITCHES | 2 | x | 0.26 | 5% | 0.25 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 |
| GORE CABLING | 1 | x | 6.53 | 20% | 5.44 | 0.00 | 0.00 | 75.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM BECKER, 1/17/01 |
| **CT&DH SUBSYSTEM** | | | **43.78** | **9%** | **40.30** | **9.10** | **-9.23** | **72.28** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| FSC | 1 | x | 32.12 | 10% | 29.20 | 19.80 | -8.30 | 72.28 | 507.04 | 422.19 | 639.36 | -0.62 | 0.00 | 0.00 | MASS FROM CLARK, 09/25/01 |
| RIU | 1 | x | 11.66 | 5% | 11.10 | -20.39 | -11.78 | 72.25 | 101.25 | 128.02 | 119.66 | 0.00 | 0.00 | 0.00 | MASS FROM GARNER, 06/19/01 - INERTIAS FROM CAD, 09/21/01 |

# Backup – Mass Report (3 of 3)

**FAME MASS PROPERTIES REPORT (English Units)** **VERSION: 10/16/2001**

| SUBSYSTEM COMPONENT | QTY | | TOTAL | UNCERT | | CENTER OF MASS | | | INERTIA ABOUT CENTER OF MASS | | | | | | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MASS (lbm) | MASS (%) | MASS (lbm) | $X_b$ cg (in) | $Y_b$ cg (in) | $Z_b$ cg (in) | $Ixx_b$ (lbm*in^2) | $Iyy_b$ (lbm*in^2) | $Izz_b$ (lbm*in^2) | $Pxz_b$ (lbm*in^2) | $Pyz_b$ (lbm*in^2) | $Pxy_b$ (lbm*in^2) | |
| **TCS SUBSYSTEM** | | | **36.27** | **10%** | **33.04** | **0.00** | **0.00** | **74.07** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| *THERMAL BLANKET, THRUST CONE* | 1 | x | 7.18 | 5% | 6.84 | 0.00 | 0.00 | 68.00 | 2000.00 | 2000.00 | 4000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, RCS DECK* | 1 | x | 1.58 | 10% | 1.44 | 0.00 | 0.00 | 54.00 | 800.00 | 800.00 | 1600.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, ELECTRONICS DECK* | 1 | x | 5.74 | 10% | 5.22 | 0.00 | 0.00 | 78.00 | 10000.00 | 10000.00 | 20000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, RADIATOR* | 1 | x | 4.54 | 5% | 4.32 | 0.00 | 0.00 | 78.00 | 10000.00 | 10000.00 | 20000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, SOLAR ARRAY* | 1 | x | 6.73 | 10% | 6.12 | 0.00 | 0.00 | 76.00 | 10000.00 | 10000.00 | 20000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, RCS TANK* | 1 | x | 1.13 | 5% | 1.08 | 0.00 | 0.00 | 76.00 | 10000.00 | 10000.00 | 20000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMOSTAT* | 26 | x | 0.51 | 5% | 0.49 | 0.00 | 0.00 | 78.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMISTOR* | 30 | x | 0.32 | 20% | 0.27 | 0.00 | 0.00 | 78.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *HEATER* | 15 | x | 0.50 | 20% | 0.42 | 0.00 | 0.00 | 76.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLACK PAINT* | 1 | x | 1.47 | 10% | 1.34 | 0.00 | 0.00 | 76.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *GREASE / RTV* | 1 | x | 0.58 | 10% | 0.53 | 0.00 | 0.00 | 76.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *TAPE* | 1 | x | 5.96 | 20% | 4.97 | 0.00 | 0.00 | 76.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| **INTERSTAGE ASSEMBLY (2)** | | | **1249.42** | **2%** | **1228.25** | **0.00** | **0.00** | **35.16** | **NA** | **NA** | **NA** | **NA** | **NA** | **NA** | |
| INTERSTAGE TOP RING | 1 | x | 12.47 | 10% | 11.33 | 0.00 | 0.00 | 57.47 | 2248.45 | 2248.45 | 4491.87 | 0.00 | 0.00 | 0.00 | CAD MODEL(.090 THK AL), 09/14/01 |
| INTERSTAGE TOP SKIN | 1 | x | 30.15 | 10% | 27.41 | 0.00 | 0.00 | 44.26 | 6211.85 | 6211.85 | 9103.23 | 0.00 | 0.00 | 0.00 | CAD MODEL(.090 THK AL), 09/14/01 |
| INTERSTAGE BOTTOM SKIN | 1 | x | 43.50 | 10% | 39.54 | 0.00 | 0.00 | 14.88 | 8844.85 | 8844.85 | 11957.32 | 0.00 | 0.00 | 0.00 | CAD MODEL(.125 THK AL), 09/14/01 |
| AKM INTERFACE RING | 1 | x | 6.40 | 10% | 5.82 | 0.00 | 0.00 | 30.12 | 738.74 | 738.74 | 1470.93 | 0.00 | 0.00 | 0.00 | CAD MODEL(.125 THK AL), 09/14/01 |
| INTERSTAGE BOTTOM RING | 1 | x | 11.85 | 10% | 10.77 | 0.00 | 0.00 | 0.64 | 1755.88 | 1755.88 | 3506.79 | 0.00 | 0.00 | 0.00 | CAD MODEL(.125 THK AL), 09/14/01 |
| SC MARMON CLAMP ASSY | 1 | x | 9.24 | 5% | 8.80 | 0.00 | 0.00 | 57.93 | 1800.00 | 1800.00 | 3600.00 | 0.00 | 0.00 | 0.00 | MASS FROM HURLEY, 03/05/01 |
| SC MARMON CLAMP RETENTION SPRINGS | 6 | x | 0.30 | 20% | 0.25 | 0.00 | 0.00 | 56.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM HURLEY, 03/05/01 |
| SC MARMON CLAMP RETENTION BRACKETS | 6 | x | 0.80 | 10% | 0.72 | 0.00 | 0.00 | 55.00 | 179.73 | 179.73 | 358.34 | 0.00 | 0.00 | 0.00 | CAD MODEL(.040 THK AL), 07/20/01 |
| SEPARATION CONNECTOR BRACKET | 1 | x | 0.67 | 20% | 0.56 | 0.00 | 0.00 | 68.68 | 183.10 | 2.76 | 185.85 | 0.00 | 0.00 | 0.00 | UPDATE |
| *THERMAL BLANKET, INTERSTAGE* | 1 | x | 7.94 | 5% | 7.56 | 0.00 | 0.00 | 30.00 | 1000.00 | 1000.00 | 1000.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| *THERMAL BLANKET, AKM* | 1 | x | 8.39 | 5% | 7.99 | 0.00 | 0.00 | 40.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | *MASS FROM BALDAUFF, 10/15/01* |
| AKM, PROPELLANT | 1 | x | 998.90 | 0% | 998.90 | 0.00 | 0.00 | 35.81 | 261549.35 | 261549.35 | 209719.34 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 09/25/01 |
| AKM, CASE | 1 | x | 75.60 | 5% | 72.00 | 0.00 | 0.00 | 35.81 | 18000.00 | 18000.00 | 15000.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 09/17/01 |
| WIRE HARNESS | 1 | x | 12.00 | 20% | 10.00 | 0.00 | 0.00 | 30.00 | 3000.00 | 3000.00 | 1000.00 | 0.00 | 0.00 | 0.00 | MASS FROM MADER, 07/06/01 |
| BALANCE MASS | 1 | x | 2.40 | 20% | 2.00 | 0.00 | 0.00 | 30.00 | 1000.00 | 1000.00 | 1000.00 | 0.00 | 0.00 | 0.00 | MASS FROM MADER, 07/06/01 |
| SAFE & ARM CONTROLLER BOX | 1 | x | 4.83 | 5% | 4.60 | 0.00 | 0.00 | 38.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MASS FROM OSBORN, 06/20/01 |
| MISCELLANEOUS MASS, FASTENERS | 1 | x | 24.00 | 20% | 20.00 | 0.00 | 0.00 | 30.00 | 10000.00 | 10000.00 | 10000.00 | 0.00 | 0.00 | 0.00 | MASS FROM MADER, 07/06/01 |

# Mechanical Peer Review Summary

- Ted Sholar APL
- Steve Vernon APL
- Rodger Farley GSFC
- Russ Barnes BEI(NRL)
- Donald Barnes Swales
- Chuck Williams Swales
- Jim Pontius Swales
- Various Design Engineers NRL

- General Comment Summary
  - Inadequate Mass Margin on Delta II 7425-10 Launch Vehicle
  - Meeting and Verifying Inertia Matrix Requirements, I.e., Ixy
  - Cleanliness and Bagging Issues During Mass Properties Testing
  - Extensive Detail in Mass Properties Report at PDR - Good
  - Honeycomb Decks and Solar Array Substrate Mass. Use Lighter Core Density
  - Electronics Deck Splice Unable to Adequately Transfer Shear
  - Provide “Flexure” Mounts for Solar Array Substrate to Electronics Deck
  - CG Location When Lifting Observatory
  - 7050-T7351 Aluminum in Place of 7075-T7351 Baseline